ILLUMINATING ENGINEERING

OCTOBER, 1949

Lighting for Machining of Small Metal Parts
Heat—A Problem of Fluorescent Lighting
Education and the Professional Engineer
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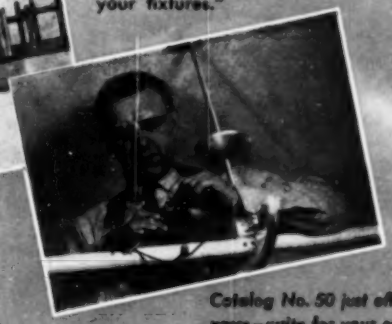

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Heat—A Problem of Fluorescent Lighting

E. H. SALTER

Heat here is referred to as a problem of fluorescent lighting because to this date we have found no method of producing lighting without heat. This problem too frequently is overlooked by the illuminating engineer, is beyond the field of operation of the electrical engineer, and, though it is of vital interest sometimes to the air conditioning engineer, he may not be in possession of all of the facts concerning it.

BOTH HEAT and light are forms of energy. A lamp is an artificial source of radiant energy in that form which is evaluated according to its capacity to produce visual sensation. As such the lamp converts energy from one form (electrical energy) into another form (radiant energy). Such a conversion never is 100 per cent efficient and energy lost in the conversion most commonly appears as heat.

Published data for the 40-watt fluorescent lamp shows that 20.5 per cent of the energy delivered to the lamp appears as light energy, 26.5 per cent as radiant heat and the remaining 53 per cent as conducted and convected heat. Compared to the incandescent lamp nearest this in lumen output, the 150-watt lamp, we find only 10 per cent of the input energy radiated as light energy, with about 70 per cent as radiated heat beyond the bulb and the remaining 20 per cent as conducted and convected heat, and absorption in the glass.

In the case of the fluorescent lamp, this heat from the lamps themselves may so increase lamp operating temperatures as to seriously affect light output. Data have been published showing the relations between bulb wall temperatures and light output, and how these in turn are affected by ambient air temperatures.

These temperature effects are important for we find that the grouping of lamps or the use of various reflector arrangement has the effect of increasing room air temperature. Fig. 1 gives the results of some measurements made of bulb wall temperatures of a group of 40-watt fluorescent lamps. Here it is seen that a single lamp burning without reflector in the open air shows a bulb temperature rise of 29°F, corresponding closely to the usual lamp rating conditions. However, as lamps are grouped and fixture parts added the bulb wall temperatures are increased by as much as 40°F, possibly corresponding to light output reduction of 20 per cent. This extreme condition was reached with three lamps burning in a glass-bottom troffer. Bulb wall temperatures approximating 20°F above rating conditions existed for one lamp in the glass bottom troffer, two lamps in an open bottom troffer, or three lamps in a closed end industrial unit. This temperature corresponds to a probable 8 per cent reduction in light.

MR. SALTER is a research engineer with the Electrical Testing Laboratories, Inc., New York, N. Y.

TYPE OF FIXTURE	NUMBER OF LAMPS 1	2	3
	BULB WALL TEMPERATURE RISE, F		
UNSHIELDED: NO REFLECTOR	29.0	32.4	35.3
OPEN END INDUSTRIAL	27.9	36.9	38.7
CLOSED END INDUSTRIAL	35.1	43.2	49.5
SHALLOW TROFFER: OPEN BOTTOM	36.9	52.2	65.7
SHALLOW TROFFER: GLASS BOTTOM	50.4	64.8	72.9

Figure 1. Bulb-wall temperatures of a group of 40-watt fluorescent lamps.

In these tests the lamps were mounted on $2\frac{1}{2}$-inch centers and the heating was due to the absorption of radiant energy from adjacent lamps, the limitation of convection currents by reflectors and the trapping of radiant energy due to the glass cover. Temperature changes of the order of those shown seriously reduce the light output from these lamps.

Fixture Problems

Not only does lamp heat affect lamp operation, but it may affect the operation of certain auxiliary equipments. The cut-out mechanism in the cut-out type of starter is a thermal device. Any temperature above 140°F may cause this mechanism to function even though the lamp may be burning quite normally. The data shown in Fig. 1 would show that, where these starters are used in totally enclosed fixtures, temperatures may go high enough to cause just this thing to happen. Experience in service in certain installations has verified this.

But the problem of heat with lighting is not limited to the heat from lamps. As a matter of fact

with the advent of the fluorescent lamp the problem has shifted largely to one centering around the life expectancy for auxiliary electrical equipment used with the lamps. This latter phase of the problem of heat came to the fore very promptly after the introduction of fluorescent lighting equipment.

Developments in Lighting Installation

When the fluorescent lamp first appeared it was used chiefly as isolated small lamps or as lines of lamps mounted on wiring strip or channel. With the advent of the larger lamps and of the two-lamp type of ballast, lamps were combined to operate in groups usually in fixtures suspended well below the ceiling. These fixtures were at first bare lamp, but as materials were developed there appeared various diffusing and reflecting media used in the production of a finished fixture.

Very soon it developed that these fixtures might be hung end-to-end so as to produce continuous lines of light. And then as time moved on, these lines of light first approached the ceiling and then moved right on into it. As a result, today a high percentage of the fluorescent lighting installations are either of fixtures mounted close against the ceiling or in the ceiling (troffers).

Each of these steps in the development of the application of the fluorescent lamp has brought a new element into the heat problem. When fixtures were suspended in mid-air practically the entire fixture surface was useful in the transfer of heat from the operating parts to the surrounding air. As the fixture approached the ceiling, a large part of this surface was rendered ineffective. And when the fixture finally was embedded in the ceiling many factors other than the fixture itself entered to determine the rate at which heat could be dissipated.

Temperature Rise

It is a fundamental law of physics that any body receiving heat will continue to rise in temperature until the rate of heat loss is equal to the rate at which it is received. Temperature rise, *i.e.*, the final increase in temperature above surrounding air, may then be taken as an indicator of the rate of heat generation (when measured under standard ambient conditions, *i.e.*, a specified surrounding air temperature) or as a measure of the rate of heat loss (as this is affected by the surrounds). It is a common practice to specify that a piece of electrical equipment, *e.g.*, a motor, should not show a temperature rise in excess of 50° C under standard test conditions. Likewise it is specified in connection with lighting equipment that the temperature rise of the ballast shall not exceed a given limit under standardized test conditions.

LAMP	LIGHT OUTPUT, LUMENS	TOTAL RADIATED ENERGY, WATTS	CONDUCTED AND CONVECTED HEAT, WATTS	TYPICAL BALLAST LOSS, WATTS
150-WATT INCANDESCENT	2600	120	30	
40-WATT 3500° WHITE FLUORESCENT	2300	18.8	21.2	8.5* 14.7**

*ONE-HALF LOSS OF TWO-LAMP BALLAST - PREHEAT STARTING

** " " " " " " - INSTANT STARTING

Figure 2. Typical heat generation of an incandescent and fluorescent lamp.

It is characteristic of lighting equipment that heat is generated both in the lamp and in the ballast, where such is needed. Typical of the normal heat generation of an incandescent and a fluorescent lamp is the data of Fig. 2. These data are, of course, taken with the lamp burning. In the case of the incandescent lamp, the end of life is marked by the filament burning through and the circuit opening. From that point on, the lamp is dead and no longer generates heat.

However, it is characteristic of certain types of fluorescent equipment that the maximum heat generation in the ballast occurs after the lamp has ceased to function as a light source. One reason for this is that the average fluorescent lamp fails, not by burnout, but by deactivation of the cathodes. When this happens the arc is extinguished. With the instant-starting types of fluorescent lamp equipment, this lamp is out and its circuit is open, but the ballast loss may be increased by as much as 10 per cent if the dead lamp is operated from a multiple-circuit ballast. When preheat starting types of fluorescent lamp equipment are used, the arc is extinguished but the starter goes into action at once, attempting to restart the lamp by closing and opening the starter circuit intermittently. Unless the starter fails, or is of the cutout type which acts automatically to stop these starting attempts after a short time, this action will continue as long as the circuit is energized and the deactivated lamp is allowed to remain in its holders. The most common form of starter failure under this condition of operation is permanent short-circuiting either by puncture of the condenser in the starter or by welding of the starter contact points. Under this latter condition, the ballast delivers the full preheating current continuously to the deactivated lamp. Typical of the heat generated is the data for the 40-watt lamp, shown in Fig. 3.

Thus it is seen that lamp failure in the case of fluorescent equipment using the 40-watt lamp, without benefit of cut-out type starters, may result in increased ballast losses of from 10 to 50 per cent.

This naturally tends to produce a corresponding increase in the temperature rise of the ballast. Measurements made at ETL have shown this increased temperature rise to cover the range indicated in Fig. 4.

Specification Limits—Ballast Heating

The role of the deactivated lamp in the ballast heating problem was recognized from the beginning in the specifications of the ballast manufacturers, and of certain groups of fixture manufacturers, where a limit was placed upon the maximum temperature rise measured on the surface of a ballast

LIGHT OUTPUT, LUMENS	TOTAL RADIATED ENERGY, WATTS	CONDUCTED AND CONVECTED HEAT, WATTS	TYPICAL BALLAST LOSS, WATTS*
LAMP BURNING NORMALLY			
2300	18.8	21.2	8.5**
LAMP DEACTIVATED, CONVENTIONAL STARTER			
***	***	12.0	12.8
LAMP DEACTIVATED, CUT-OUT STARTER			
0	0	0	6.5
LAMP DEACTIVATED, INSTANT STARTING			
0	0	0	15.7

*ONE-HALF LOSS OF TWO-LAMP BALLAST. OTHER LAMP BURNING NORMALLY IN EACH CASE.

**FOR INSTANT-STARTING TYPE, 16.7 WATTS.

***GLOW ONLY AT CATHODES; LITTLE ENERGY RADIATED.

Figure 3. Typical heat generated by a 40-watt fluorescent lamp.

case under this condition of operation. This was done when specifications sponsored by other groups either ignored the subject of ballast temperature altogether or treated it with reference to normal lamp burning conditions only. At the suggestion of ETL, these conditions now have been recognized by various other groups writing specifications.

Recent tests at ETL have shown that the measurement of temperature rise on the surface of the ballast case may not be a reliable means of determining what temperature conditions are in the vital parts inside the case. Coil temperatures and capacitor temperatures may bear different relations to ballast case temperatures in various makes and types of ballasts. With this knowledge, new specifications now are in the process of development to the end that specified temperature measurements should yield concrete information as to conditions in the working parts of the ballast.

The operation of luminaires with deactivated lamps or short-circuited starters can be justified, if at all, only on the assumption that the condition will exist during but a short interval, for example, less than the time required for the ballasts to attain their equilibrium temperatures under this condition (a maximum of 3 to 4 hours). Fortunately, a starter attempting to start a deactivated lamp causes an intermittent flashing of the lamp which draws attention to the situation and even constitutes sufficient annoyance to induce the user to remove the deactivated lamp more promptly than he would otherwise. This favorable aspect of the matter has caused the excessive temperatures mentioned above to be viewed with a certain degree of complacence. Experience in the field, however, has not fully justified that attitude.

The advent of the cut-out type of starter brought some hope that the excess heating following lamp deactivation would be a thing of the past, but in the past a manufacturer has had no assurance that these starters will be used once the fixture is installed. This type of starter operates to disconnect a deactivated lamp from the ballast circuit after a reasonable period of attempted but unsuccessful starts. Unfortunately, these starters are somewhat more expensive than the ordinary types and for that reason may be replaced by these other types when starter failure occurs. ETL devised a means whereby a fixture equipped for cut-out starters has to be provided with cut-out starters but this is just beginning to find its way into use in the field. Where a fixture is so equipped, specifications set limits for operation only with all lamps burning.

Because in some instances ballasts supplying instant-starting lamps may show greater temperature rises when one lamp is deactivated (out), specifications usually call for examining such ballasts under all combinations of burning or unlighted lamps, except that it is considered reasonable that a ballast will not be allowed to operate with more than one lamp unlighted.

Factors in Fixture Constructions Which May Be Utilized for Reduction of Ballast Temperatures

Fluorescent luminaire designs such as to keep ballast temperatures within limits should do much

PORTION OF BALLAST EXAMINED	ADDITIONAL TEMPERATURE RISE DUE TO DEACTIVATED LAMP OPERATION, C
BALLAST CASE	9 to 39
BALLAST COILS	17 to 72
BALLAST CAPACITOR	7 to 27

Figure 4. Corresponding temperature rise of the ballast.

toward insuring reasonably long life of ballasts. An idea of the effectiveness of the certification programs in solving the heating problem may be had from the fact that many luminaires that would not satisfy the ballast temperature requirements when first submitted by the manufacturers have been enabled to pass by the incorporation of minor alterations. It may be inferred from this fact that many luminaires offered to the public without benefit of certification may induce early ballast failure through overheating.

In general, the reduction of the temperature of a fluorescent lamp ballast in a luminaire involves improvement of the facilities for the dissipation of its heat through one or more of the three available processes, namely, conduction, convection, and radiation.

Conduction of heat from the ballast is most readily accomplished by mounting it in intimate contact with a relatively cool surface of a conducting material (metal). The mounting surface should be flat in order to make contact with as large an area of the ballast as possible. *It is almost impossible to keep the temperature of a ballast in a typical enclosure within the desired limits without the assistance of conduction in dissipating the ballast heat.* This is true because the temperature of the air inside a well-designed ballast housing averages 40°C (15°C above a room temperature of 25°C).

In the early days of fluorescent lighting, isolation of the ballast from the mounting surface by interposition of washers of absorbent material was advocated for the purpose of lessening the transmission of hum to the luminaire. Developments in the assembly of the ballast, however, served to check this hum at the source. For this reason, and because the interposition of washers between the ballast and its mounting surface effectively prevents the dissipation of heat by conduction, it now is considered preferable to mount the ballasts in close contact with a heat-conducting surface. (In this connection it should be pointed out that with the application of fluorescent lighting to the home and other locations of low background noise, the question of fixture noise again is coming to the fore. Present day fixtures probably are amplifiers of ballast noise. Further control of noise through fixture design offers promising results.)

Mounting a ballast on straps which make contact only with the mounting ears of the ballast is almost as harmful in preventing heat flow from the ballast as mounting on washers. In fact, any mounting method which does not bring at least one full ballast surface into intimate contact with the metal housing of the fixture is imposing a definite handicap on the ballast. Such conditions are bound to cause the ballast to operate at higher temperatures than are necessary and any unnecessary temperature rise steals life from this equipment.

If the temperature of the ballast is excessive even though mounted with one surface in contact with a conducting material, further reduction may be achieved by placing other conducting bodies in contact with other surfaces of the ballast. It usually is not practicable to arrange for conduction of heat from more than two or three surfaces of the ballast and generally two are sufficient. It should be remembered that, if the conducting body in contact with the ballast is to be effective, it in turn must be able to dissipate the heat conducted into it by radiation, by convection or by conduction into other cooler bodies. An effective arrangement for dissipation of ballast heat by conduction is to make the inside height of the ballast housing equal to the height of the ballast so that the ballast is simultaneously in contact with both the bottom and the cover of the housing. Examples illustrating the method of reducing ballast temperatures by improvement of facilities for conduction of heat away from the ballasts are shown in Fig. 5.

Direct *convective* dissipation of ballast heat requires the circulation of a current of relatively cool air over the ballast. Openings in the ballast housing for ventilating purposes are ineffective unless they can be so located as to secure chimney action to induce a flow of air over the ballast. Furthermore, Underwriters' Laboratories Standards set very definite limits to permissible openings in a fixture housing. Stagnant air surrounding a ballast is of no value for cooling purposes. If the air entering the ballast housing is preheated by passing over the lamps its effectiveness is materially reduced. Indirect convective cooling of the ballast is

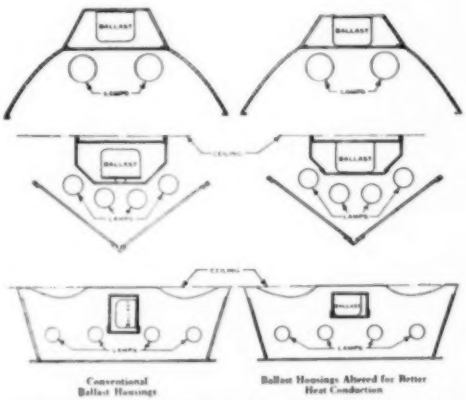
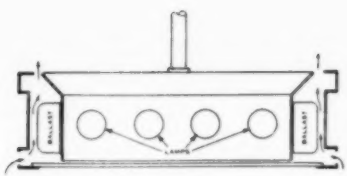
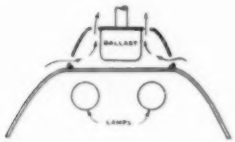
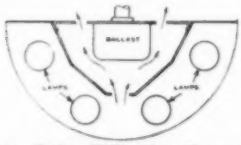
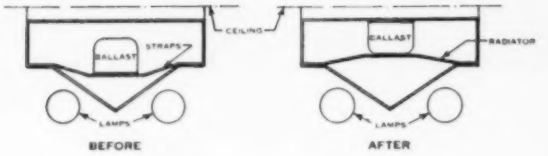


Figure 5. Examples of methods of reducing ballast temperature by improvement of facilities for conduction of heat away from the ballasts.









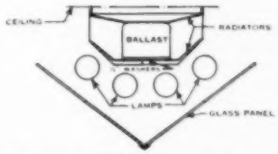


Figure 6. (Left) Utilization of convection for ballast cooling. Figure 7. (Right) Luminaires equipped with radiators for ballast cooling.

accomplished by arranging conditions to induce a flow of relatively cool air over the outer surface of the ballast housing. Ceiling luminaires and luminaires in which the lamps and ballast housing are partially or completely enclosed within diffusing glass (or similar material) are practically beyond the possibility of convection cooling. Fig. 6 is an example illustrating the employment of convection for the reduction of ballast temperature.

Radiation may be employed in several ways as a means for reducing ballast temperatures. The first consideration is the ballast surface which should have good radiation characteristics and as large an area as is consistent with other design considerations. Good radiation properties are insured by finishing the ballast with a paint containing a non-metallic pigment rather than with a bright metal surface. The effective radiating area of a ballast may be increased by arranging auxiliary metal plates in contact with one or more surfaces of the ballast. These so-called radiator fins should extend beyond the ballast and should themselves have good radiating properties. Examples illustrating the application of supplementary radiators are shown in Fig. 7.

Heat radiated from the ballast goes first to the walls of the ballast enclosure. There it is partially reflected, and partially absorbed. The absorbed heat is largely reradiated, partially to the interior of the enclosure and partially to the outside. Obviously it is advantageous to arrange conditions so that the heat reflected and reradiated into the interior of the enclosure will be a minimum. These objects may be arrived at by painting or enameling both inner and outer surfaces of the ballast enclosure with a non-metallic pigment. It is of little value to paint one surface and leave the other with a bright metal finish. The color of the paint is not important. White paint (non-metallic base) or enamel is substantially as good a radiator and absorber as black paint or enamel when dealing with low-temperature radiation. Aluminum paint is a poor absorber and a poor radiator. It is advantageous also to place the ballast enclosure in relation to other elements of the luminaire so that it may radiate freely to the outer spaces.

Substantial reduction of ballast temperature may be achieved by judicious placing of the ballast or ballasts within the enclosure. For instance, the surface of the ballast enclosure adjacent to the lamps usually is hotter than other surfaces because it absorbs heat from the lamps. This is especially true in the regions near the lamp cathodes, where greatest heat dissipation takes place from the lamps. It therefore is wise to mount the ballast on one of the surfaces of the enclosure which is not exposed to radiation or washed by convection currents from the lamps.

Ballasts usually are hotter at one end than at the other. If a luminaire contains more than one ballast it usually is good practice to arrange them so that the hotter ends point away from each other and to allow as much space between ballasts as is practicable.

The above discussion indicates the availability of a considerable variety of means for reducing ballast temperatures. The relative values of the several expedients will vary with the design of the indi-

vidual luminaire. In many instances one minor modification in a luminaire is sufficient to bring it within specification requirements. In others, it is necessary to employ more than one and in some instances most of the available means for temperature reduction must be employed.

Municipal Regulations

Where fixture specifications practically require the mounting of the ballast in contact with the mounting surface to secure satisfactory dissipation of heat, this requirement runs into direct conflict with certain municipal regulations that arbitrarily require an air space of at least one-quarter inch between the ballast and the mounting surface. This requirement has no sound basis and strong efforts have been exerted toward its modification, but the latest published copies of the electrical code still carry this regulation. Where local authorities insist upon the insertion of washers between ballast and mounting surface in a luminaire which has been certified for operation with the ballast in contact with the mounting surface, they effectively nullify the safeguards which the certification program has set up for the benefit of the user.

Factors in Fixture Installation Which Influence Ballast Temperature

It is fairly obvious that the ready transfer of heat from the ballast to the ballast enclosure is only a part of the picture of dissipating ballast losses. Unless the fixture is then able to pass this heat along to surrounding objects or to the atmosphere, those parts of the fixture which receive this heat will be forced to high temperatures and the ballast in turn to still higher temperatures. The same basic laws obtain, namely, that a body will continue to rise in temperature until its rate of heat dissipation equals its rate of heat gain and this heat must be dissipated by conduction, convection, and radiation.

In recognition of the heat dissipation problem as applied to fixtures, a recent fixture specification has classified fixtures according to the service for which they are designed into pendant (*P*), surface mounting (*S*), and recessed (*R*). For the purposes of this specification, a pendant fixture is one made for mounting 5 inches or more below the ceiling surface, a surface fixture less than 5 inches below the ceiling surface and a recessed fixture wholly or partially above the ceiling surface.

The pendant type of fixture usually is so designed that the ballast enclosure is exposed to room air on at least three sides, with the result that this type of fixture gives ready play to heat dissipation by convection and radiation. With air free to move around the ballast housing, heat dissipation is chiefly a matter of the surface area through which the surrounding air can wash this surface. Radiation from that surface to surrounding objects will assist in the heat dissipation. Direct conduction is absent for all practical purposes since these parts make contact only with the body of the fixture surface. Such fixtures normally are most readily arranged to give reasonable ballast temperatures.

As the mounting position approaches the ceiling surface there is less and less opportunity for free air circulation around the ballast enclosure of the fixture. This becomes most pronounced as face (flush) mounting is approached. Tests have shown that in many cases ballasts run from 5° to 10°C cooler when the fixture is mounted one inch below the ceiling than when mounted directly against the ceiling. When against the ceiling convection and radiation as means of dissipating heat are limited to those surfaces not making contact with the ceiling but still open to free air contact. The air adjacent to the ceiling, however, is likely to be stagnant or at best sluggish in its movement. For this reason heat dissipation by convection is greatly reduced. Heat loss by radiation is limited to those objects which the ballast enclosure can "see" from this location and this likewise is likely to be reduced. Direct conduction, however, does come into play due to contact between the fixture and the ceiling. Since common building practice is to make ceilings of thermal insulating materials, the rate of heat dissipation by direct conduction is likely to be low. In spite of good heat transfer conditions from ballast to ballast, housing such fixtures are difficult problems in heat dissipation. The practice required in some city codes, of mounting the fixtures half an inch to one inch below the ceiling is helpful in securing lower ballast temperatures, but even this will not suffice in a large percentage of fixtures.

When a fixture is recessed wholly or partially into the ceiling this problem may take a turn either for the better or for the worse. If this recessing is into the space between joists or beams supporting the floor above, the problem is likely to become more difficult of solution. On the other hand, if the fixtures are recessed into a false ceiling with adequate air space above there are various approaches indicated which make reasonable ballast temperatures a possibility. When set directly between floor beams, there is no convection to outside air possible, only convection to carry the heat to the floor and ceiling structure. This supplements the dissipation by radiation to these same parts. But, again because these materials are likely to be thermal insulators, the rate of heat loss is bound to be low unless the fixture temperatures are forced

quite high. This results in overheating of the ballasts. However, when the fixtures are recessed into a false ceiling the space above may be ventilated and an excellent operating condition produced. Where this space above the false ceiling is large and not naturally at a high temperature (the space directly below a roof is likely to be at a high temperature at certain times) it may be possible to secure enough heat dissipation by convection without artificial ventilating means.

Since it frequently is not possible to tell when a fixture is submitted for test just what operating conditions may be when it is installed, the fixture specification referred to above indicates that for test purposes surface-mounted fixtures shall be mounted against the ceiling or spaced below the ceiling with such fittings or spacers as the manufacturer normally supplies for surface-mounting applications and that recessed fixtures shall be mounted in a trough of rectangular cross-section such that each wall shall be half an inch from the nearest portion of that fixture. Thus it is provided that tests shall be made under what is likely to be the most severe operating condition. Such fixtures as comply with the specified ballast temperature limits may then be certified as to this compliance.

Interchanging of Ballasts

Though a ballast of one type and brand may be operated in a given luminaire with satisfactorily low temperature rise, it does not follow that ballasts of other types or brands may be substituted even though the latter be designed to operate the same lamps upon a circuit of equal voltage and frequency and to satisfy the same specified temperature limits. The reason for this is that the pertinent specifications require that the ballast temperature rise shall not *exceed* a certain limiting value under specified conditions. Ballasts which satisfy this requirement do not necessarily generate heat at equal rates and luminaires are not equally effective in dissipating ballast heat. Therefore, while one ballast may perform satisfactorily (from a thermal point of view) in a given luminaire, a second ballast (of another type or brand) installed in the same manner in the same luminaire may overheat when operated under similar conditions. On the other hand the second ballast may perform satisfactorily in another luminaire which has better facilities for dissipating heat. Certification of complete luminaires is the best method of insuring ballast temperatures compatible with durability.

Certification of Existing Fixtures

During the first eight months of 1948 it was found that 97 per cent of the pendant type of fluorescent fixture submitted for certification tests either complied with the specification requirements as to ballast temperature as submitted or were readily modified so as to comply. During this same period only 33 per cent of the fixtures designated as for surface mounting were found to comply. In this latter case, none of these luminaires was supplied with special hangers of any sort so that all tests were made with the fixtures mounted close against the ceiling. It is not known how many additional fixtures would have been found to comply had they been spaced down to 5 inches below the ceiling. In this same period there was not one fixture of the recessed type which was found to meet the temperature requirements.

The above condition is one which should not be corrected by further increasing the allowable temperature rise, since there are some indications that the present limit may be too high. There would appear to be only two possible sure ways out of this situation, one to provide positive means for dissipating fixture heat so that the ballast may be made to run cooler and the other to provide ballasts which either can take the higher temperatures without damage or which will not have the inherent temperature rise of present designs.

Where means for dissipating the heat can be provided, such modifications in fixture construction probably would prove most economical. Ballasts which will withstand the temperature, or of lower temperature rise, are not now available and probably would be considerably more expensive than present ballasts if made available. These are factors which manufacturers will have to consider in connection with the certification of fixtures. Fixtures can be certified for the extreme operating conditions encountered in surface or recessed mounting only when it can be demonstrated that ballasts will have a reasonable operating life under those conditions.

Bound Volumes of American *Illuminating Engineer* Available

Two extra copies of bound volumes 6 and 7 (March, 1911 to January, 1913) of the American *Illuminating Engineer* magazine are available at I.E.S. headquarters. Since volumes of this journal are now quite rare, some I.E.S. member may be interested in obtaining these books. Anyone wishing the copies may write to C. L. Crouch, Technical Director, Illuminating Engineering Society, 51 Madison Avenue, New York 10, N. Y.

Lighting the People's City Bank —

My Most Interesting Job

HUGH S. JAMES
Pittsburgh Section

LIGHTING the People's City Bank at McKeesport, Pennsylvania was my most interesting job because — the lighting plans in the remodeling program for this building, at first considered secondary to all other reconstruction, proved themselves so thoroughly, that the entire program was reversed — making all other construction plans contingent on the lighting layout. Lighting the Bank Room was the third step in the general building improvement program. Each of the previous areas had included extensive remodeling and construction, with lighting plans being provided during construction stages. Consideration of lighting problems was secondary to construction, but the results after the completion of each step, indicated that the one single thing which had effected the most notable improvements was the new lighting system installed in each area.

When the third stage of this program was reached, no plans were drawn up for remodeling or reconstruction of any part of the banking room. The first and only consideration was to provide a new lighting system with modern lighting equipment to provide adequate illumination in accordance with latest standards. All ultimate changes involving reconstruction were based on the proposed plan of lighting which was submitted. In this job the lighting plan was not a secondary consideration, but actually dictated the course of the whole job.

One of the most interesting features of the lighting installation was that it was the first large application of a louverall ceiling in this district. It very pleasingly combines the use of fluorescent and incandescent sources in a pattern arrangement to provide most effectively specific levels of illumination over the various work and service areas. These factors influenced the Board of Directors of the bank, as well as the contractor, to extend their plans for doing a complete job of reconstruction on the ceiling to include this complete plan.

This installation was judged winner of the contest "My Most Interesting Job" conducted by the East Central Region, and presented at the 1949 Regional Conference. MR. JAMES is with the Duquesne Light Co., Pittsburgh, Pa.

For the lighting man who plans the installation, many factors not always related to the technical aspects of the lighting layout, make the job of special interest to him. To give expression to such men, the Sections and Chapters comprising the East Central Region conducted contests this past year for "My Most Interesting Job." The winners from each Section and Chapter competed at the Regional Conference for the winning installation. Presented on the following pages are, first, the Regional winner, which was also the winning representative from the Pittsburgh Section, and the runners-up from the other Sections and Chapters of the East Central Region.

The Lighting Problem

The immediate problem of relighting this area was one of providing illumination from a high ceiling (21 feet 6 inches high) over such a large area, and the treatment of this area in such a way as to illuminate efficiently the entire floor without prohibitive cost, construction, and power increases.

A cost analysis favored a louverall ceiling in preference to an all-suspended ceiling and recessed troffers. The combination of louverall ceiling and center suspended ceiling was chosen both from an atmosphere and architectural consideration, as well as careful planning for illumination values desired for three important work areas — behind the cashiers' cages, cashiers' counters and public area.

The single outstanding feature of this installation during construction, was that a rolling scaffold was used so that each bay could be completed as a unit and then moved to the next without interruption of normal business. The final results are completely satisfactory to the bank executives and have already brought requests for further study of illumination problems in other areas of this building.

The effective and pleasing lighting results of some 75 footcandles average on the cashiers' counters and 60 footcandles average on the office area back of the counter, were achieved with the rather

unique application of three types of equipment using both incandescent and fluorescent sources. As shown in the picture below, these include: A. Ten-inch square recessed panels with 300-watt clear lamps in a concentrating silver mirrored glass reflector equipped with a pattern louver. B. Eight-foot channel having two 40-watt white fluorescent lamps placed end to end with channel mounted on the ceiling at 18-inch centers and equipped with single lamp reflectors, semi-concentrating. An egg-crate louverall ceiling is suspended 18 inches below the ceiling in 3′ x 3′ units. Louvers are 2″ x 2″ x 2″, with 45° shielding. C. Troffers recessed flush with the ceiling, each four-foot section using three 40-watt white fluorescent lamps and high power factor auxiliaries, and equipped with egg-crate louvers.

The Bank Room before relighting.

Color schemes worked out for the installations provided a white acoustical ceiling having a reflector factor of 80 per cent; flat white beams and wood trim at 80 per cent reflectance; light green side walls having a 48 per cent reflectance; light marble floor at 33 per cent, and medium marble cashiers' counter having a reflection factor of 5 per cent.

Results of "My Most Interesting Job."

A Unique Home Lighting Installation—

My Most Interesting Job

HOWARD S. KREITZBERGER

HOME LIGHTING is usually an interesting lighting job anyway, but in this installation an interesting problem existed in the lighting of a very beautiful collection of oil paintings. The living room to be lighted was in the home of Alvin Markle, Jr., Luzerne County, Pennsylvania, whose hobby is collecting oils, and the valuable collection was hung almost completely round the room.

A very pleasing solution was reached with recessed units with prismatic lenses, an offset of 15 degrees, using 200-watt incandescent lamps. At the sides of the room, these were installed on approximately three-foot centers, with one-foot spacing at two corners of the room.

When consideration was first given to such an installation in a living room, it was feared that the appearance would be too "commercial" in atmosphere. Wall colors and other factors, however, were very carefully discussed with the decorator and the entire installation has an exceptionally warm and pleasing atmosphere.

The job proved so satisfactory to Mr. Markle that he requested a similar treatment of his library. This was a room lined almost completely with bookshelves, and having a large fireplace, also flanked by books. The same recessed ceiling units were installed here, on four-foot centers and at each side of the fireplace. The results are excellent — the whole job most satisfying and interesting.

This installation represented the Eastern Pennsylvania Chapter in the contest "My Most Interesting Job" conducted by the East Central Region. MR. KREITZBERGER is a lighting consultant in Hazelton, Pa.

Relighting a Stationery Store —

My Most Interesting Job

L. H. CLEARY

THE RELIGHTING of the Stockett-Fiske Stationery Store in Washington, D. C., was in every sense a *re*-lighting project. The existing lighting system, shown in the upper right-hand photograph, was installed in 1928 and consisted of 300-watt and 150-watt Trojan type units suspended on chain hangers throughout the 30 ft x 120 ft building. Overall lighting averaged from 2 to 5 footcandles — a most gloomy picture by present-day standards.

A careful survey of the type of merchandise, its colors and other special requirements, was made before drawing up the modernization plan. A new ceiling was installed, dropped about 4 feet to the bottom of the deepest beam, of mineral fibre tile, 12 inch by 12 inch, having a reflectance of 80 per cent. Walls were painted genoa green (75 per cent); floors are dark brown (10 per cent) and light-colored (20 per cent) squares of linoleum.

Continuous row three-lamp flush units using 40-watt 3500K lamps; and four-lamp surface mounted units with 40-watt 3500K lamps provide some 70 footcandles over the sales area, with satisfactory brightness values. Under the mezzanine the units are so arranged that either two or three tubes may be used, depending on the changing requirements in that area. Readings at present are 42 footcandles horizontal and 24 vertical along the walls. Illumination levels in the offices average 78 footcandles in the bookkeeping department, 66 footcandles in the front office and 45 footcandles in the small office.

To provide for the future, a continuous strip of plugmold with six receptacles, equally spaced, runs on the underside and along the outer edge of the mezzanine on each side, for possible spots or signs. There is also provision for show cases along each aisle, where there are six floor outlets for attachment to any equipment which may be installed in these locations.

The numerous expressions of satisfaction we have received from the store's owners would indicate that the installation fulfills the requirements of our objective — namely, attraction, appraisal and atmosphere.

Before relighting — circa 1928.

Same area after relighting.

This installation was chosen by a committee of the Capital Section as their candidate in the contest "My Most Interesting Job" conducted by the East Central Region. Mr. Cleary is an illuminating engineering consultant in Washington, D. C.

The Big Palestra — My Most Interesting Job

G. WAGNER

THE UNIVERSITY of Pennsylvania Palestra is a large gymnasium seating between 8000 and 9000 spectators. Lighting it was a challenging and interesting job. Instead of one problem, as in most jobs, solutions were required for three separate problems including adequate illumination for taking television and motion picture training films. As far as I know, this is the first gymnasium to be lighted for the express purpose of taking television and moving pictures, and I believe it can be considered a pioneering example.

Problem No. 1 was to provide adequate illumination for movies of basketball and other indoor sports for training and visual teaching purposes. Motion picture engineers stipulated 100 footcandles of non-stroboscopic illumination, as a minimum. Fifteen twin high-bay reflector units for 1000-1500 watts were installed over the playing area, with seven single high-bay reflector units on each side of the gymnasium. For requirement No. 1, 100 footcandles was obtained by using all of these units lamped with 1500-watt lamps burned at 10 per cent overvoltage. Lamp life covers a season's play.

For requirement No. 2 — television pictures for which a minimum of 50 ft-c was required — the same units were employed, but with 1000-watt lamps at rated voltage. Laymen felt these pictures were satisfactory, but professional movie men would not agree. For professional quality, a level of 100 footcandles would be necessary.

Problem No. 3 was to light the playing area for indoor sports — for which the present recommended level is 30 footcandles. This value is obtained from the two rows of single reflector units and the center row of twin units, lamped with 1000-watt lamps.

The new lighting system has been designed with wiring for 20 watts per square foot over the playing area, as compared with one watt per square foot for the former installation. The results have been eminently satisfactory to players, spectators and television engineers. College officials, architects and consulting engineers have visited and inspected the installation and as a result it is now likely that the new University of Pittsburgh Field House, as well as the new Penn State gymnasium will be lighted in a similar manner.

This installation was the winning representative from the Philadelphia Section in the contest "My Most Interesting Job" conducted by the East Central Region. MR. WAGNER is an application engineer with the Philadelphia Electric Co., Philadelphia, Pa.

Relighting the Gunther Plant —

My Most Interesting Job

C. H. BRONNER

WHEN THE Gunther Brewing Company of Baltimore decided to modernize its offices, one of the first problems to confront the plant engineer was how the new offices were to be lighted. This problem was somewhat complicated by a sloping ceiling and a considerable number of exposed pipes and ducts that could not be easily rerouted or eliminated. The services of an architect and consulting engineer were obtained and the lighting problem was considered simultaneously with the structural and decorative changes. Of all the possible methods considered, a louvered ceiling seemed to be the most logical solution; first, because it would eliminate the necessity of a suspended ceiling to cover the existing obstructions; and second, a maximum unobstructed ceiling height could be maintained.

In the Reception Room shown the 17′ x 20′ room is lighted entirely by 115 40-watt, five 20-watt and eight 15-watt 4500K fluorescent lamps in reflector strips 9 inches above the plastic louver ceiling, and spaced 18 inches between rows of strip. Some 115 footcandles is obtained after two months' operation. In this room two of the walls are contoured, which necessitated cutting the standard section of louvers on the job. A wood strip around all of the room acts as a support for the end louver sections and a finish between the louvers and the walls. An illuminated mural decorates one wall while on the opposite wall there is an illuminated glass panel which required considerable experimentation in the placing of the lighting units to bring out the corregations in the glass in a manner satisfactory to the architect.

The general office, 32′ x 42′ in size, is lighted in a similar manner, obtaining 120 footcandles after two months' operation. All windows in this office were eliminated, which in addition to reducing heat losses and eliminating street noises, gave the architect a free hand in contouring and the decorative treatment of the walls.

Louverall ceilings have been used throughout the installation, including corridors and four private offices. Excellent values for both quantity and quality of the illumination have been obtained.

This installation represented the Baltimore Chapter in the contest for "My Most Interesting Job" conducted by the East Central Region. MR. BRONNER is with the Consolidated Gas, Light and Power Co., Baltimore, Maryland.

Education and the Professional Engineer

By JOHN O. KRAEHENBUEHL

The importance of an established professional standing and the related matter of collegiate training for illuminating engineers are discussed objectively by an engineering educator in the hope of stimulating thoughtful discuscussion and constructive action.

BEFORE IT is possible to determine the nature of the curriculum which must be followed in training an engineer it is necessary to analyze the profession generally. Since every profession centers its ethics in an organization to represent its interests and develop its usefullness, any study must be inseparately connected with this organization and its professional standing. Since the Illuminating Engineering Society is the professional organization of illuminating engineers, the educational program for training its prospective members must center around the needs of the Society membership.

For the past fifteen years there has been a tendency for the industrial-social structure of the United States to separate into distinct labor and management groups. After our country developed an industrial as well as an agricultural economy the first movement was toward powerful industrial combines, which by many short-sighted actions brought down upon themselves such controls that both their profits and independence were restricted. At the same time the labor movement, through its growing strength, attempted to exercise the same type of control over the life of the general public as was being exercised by industrial combinations. The engineer sees in himself a person better fitted for independent professional standing than as a major factor in either management or labor actions.

During the period in which older professional groups were establishing themselves, the engineer lacked a truly professional status. On the presumption of protecting the public the legal and medical professions were busy with legislation to set high standards through registration and to protect themselves against laws which did not maintain or advance their professional status. The engineer continued to take his position for granted and did little to foster legal activities which would better define engineering as a profession. In addition the engineer left educational training entirely to the educator whereas the legal and medical professions took a prominent part in formulating the course context and the period of educational training.

J. O. KRAEHENBUEHL is Professor of Electrical Engineering, University of Illinois, Urbana, Ill.

Today there seems to be a definite change in the attitude of the professional engineering societies, a movement which should be observed by the Illuminating Engineering Society. There is now the Engineer's Council for Professional Development, (ECPD), which inspects, evaluates, and certifies engineering curricula in engineering colleges. Also most states have some form of registration for engineers. The ECPD is exerting some influence upon the curricula in the engineering school, particularly concerning the addition of courses in the humanities to the heretofore rather restricted field of engineering education, which was largely confined to the specific science. If history repeats itself, as it undoubtedly will, we may expect a progressive increase in control over the educational program of those wishing to enter the various fields of engineering.

If a measure is to be made of the standing of the I.E.S. as a professional organization some standard units must be considered. What are some of the functions associated with the operation of a professional society? These may be listed in a broad sense as:

1. Development of a nomenclature.
2. Development of standards and testing procedure.
3. Dissemination of knowledge pertaining to the profession.
4. Compilation of established knowledge.
5. Establishment of professional development.
6. Punishment when ethical precepts have been violated.

How does the Illuminating Engineering Society meet these requirements?

1. *Nomenclature* — This is the specific language of the profession and so should be honored. Unless all members of the profession speak the same and a

very specific language there will always be a doubt as to the meaning when thoughts and ideas are to be transferred. This does not mean that no words are to be added or obsolete words eliminated. In a true profession which is developing, these changes become a necessity but they must be orderly and receive the approval of the profession.

Has our Society effectively met this requirement? This does not seem to be the case. Our nomenclature, at the present time, very satisfactorily represents the science but is woefully lacking in the definition of terms used in the art of the professional engineering practice, (even the frequently used term, "glare," fails to be specifically defined). Once a nomenclature has been standardized its use in publications and meetings of the Society should be considered mandatory.

To the writer and the educator language is the most important tool in the transfer of thought. The student must accumulate his knowledge, for the most part, from the text books and papers in his profession. This is even more important in his development after graduation. Change of nomenclature from one text to another and from one paper to the next is one of the greatest obstacles in developing knowledge in any specific subject.

2. *Standards and Testing* — In this division the Society may be said to be superior. This has always been an active function, and there has been freedom of change as the demand arose. The written record in this instance can allow more deviation than in the nomenclature. The change of test procedure does not make the determining of past practice as inaccessible as does a language change.

3. *Dissemination of Professional Knowledge* — The continued publication of accumulating knowledge as it develops in the Society, from its early inception, marks one of the standards of a true professional organization. Our publications are an endless storehouse of useful knowledge. They seem to have been well balanced between the science and the art of lighting.

To the educator the Society publications are of major value. He draws from them in developing text books and uses the more recent publications for class reference, for it is impossible to keep text books up-to-date. In a more profound study in the profession, as is necessary in graduate work, the published papers are the text material for the student.

4. *Compilation of Established Knowledge* — In the publication of the Lighting Handbook the Society has taken a step that has not been considered by most engineering societies. Some few organizations take the responsibility of assembling that knowledge which has stood the test of time into a formal publication for its members. The action of the Illuminating Engineering Society along this line has been much more extensive than that of any other engineering society publication.

The nature of the material published is different from the development of the nomenclature of the Society. In the handbook, as now published, the material deals mainly with the art of the profession with a minor interest in the science as contrasted with the present nomenclature, where the emphasis has been on the science. Future expansion in the language and compilation of established knowledge should be directed toward an adjustment of these shortcomings, a better balance between the nomenclature and the Handbook.

5. *Establishing Professional Development*—The Society recognizes the professional development of the individual through its various ranks in membership from Student Member to Fellow. This is in accord with good society and professional practice but its value lies mostly in the method of election to this highest rank. If such elections are based upon sectional demand or political expediency the rank loses its value and the Society loses its standing in the profession. The selection must be based upon merit and service to the profession.

6. *Punishment When Ethical Precepts Have Been Violated* — This is a practice which some professions exercise with great zeal. The engineering societies have not developed a standard of ethics and do not condemn through direct action that which reflects discredit upon the profession. It is to be expected that in the future a code of ethics may be established in more than printed form — most societies through addresses and through printed suggestions have advanced such codes. Once a code has been established, then individuals may be cited for violations and dropped from the Society.

It behooves the educator to teach a code of ethics to his students because the objective of the educational process is not only to train an individual to earn a living but to so live that he will be a credit to the training he has received. An ethical code is the most difficult to teach because success in the public mind is allied with the accumulation of wealth and not always with service rendered to the community. The educator must bring to the attention of the student that both goals may be attained at one and the same time and that the first is likely to be associated with the second.

Such concepts provide the guiding principles upon which the educator builds the training program for those who will later become part of a professional life and organization. The illuminating engineer, in most instances, has not been trained for his profession but for some other profession and

by the workings of fate has found himself interested and employed in the field which encompasses the production, specification or the construction of devices used in producing artificial light. No one has conferred upon him the Degree of Illuminating Engineering and he would be hard pressed to define the professional illuminating engineer, even though he does not hesitate to call himself an illuminating engineer.

In the past the engineering school has not looked with favor upon the development of curricula which would inherently contain the subjects blending a scientific education with the study of the construction and behavior of human beings. In the field of most engineering it makes little difference as to the human elements involved, for the bridge, the engine, or the electrical motor will work equally well independent of the user. In the instance of lighting, and heat and ventilation, the prime object is to satisfy the human being and augment his comfort, also in illumination satisfaction of the esthetic senses must be achieved.

Even an elementary consideration of the educational problem immediately indicates that the individual training programs of the electrical engineer, the architect or the eye specialist do not provide an answer to the problem. There must be a cutting-across these fields for an individual trained to engineer lighting installations which will serve in both quantity and quality, and in an esthetic sense. Basic training is highly desirable for further development with the passing years, however, the broadness of illuminating engineering from a physical, psychological and physiological sense must be recognized. Considerable pessimism exists among engineering educators because in the past the industry has not been receptive in absorbing individuals with special training in Illumination. This may be because the training, while specific, was not coordinated or comprehensive.

In the determination of any curriculum it is necessary to consider the positions to be filled by the graduate in Illuminating Engineering. Table I gives the Electrical Engineering Options at the University of Illinois and the subdivision of both the functions and responsibilities which the individual may face in following the profession.

In this discussion it is assumed that the student selects the Illumination Option although he is always taught that he is an electrical engineer and that he is being trained so as to be able to function in any of the three optional fields.

Shortly after graduation the individual will find himself with technical responsibility, usually under an experienced engineer, therefore, his immediate needs are for technical training. He will have very

TABLE I

Electrical Engineering
(a) Communication
(b) Illumination
(c) Power

Function	
Application	Production
Construction	Research
Design	Sales
Development	Service
Operation	Teaching

Test *Responsibility*
Technical
Supervisory
Executive

little contact with management and to his surprise after four years of intensive training no one will ask his opinion or weigh very seriously any of his ideas. He will during this period use extensively those things he has learned in his courses which apply directly to the field in which he is working and must assimilate the particular knowledge and practice of the organization with which he is associated.

The training received in college should prepare him for these first few years. Thereafter it is assumed that if he is to develop into responsible supervisory capacity and eventually into executive responsibility he will have to do additional work, chiefly in the fields of finance, administration and personnel. Therefore, the curriculum (outlined in Fig. 1) is developed to give the individual technical information and procedure in the fundamentals with enough information and vocabulary so that he can develop himself in those subjects which deal with administration and the humanities. Special emphasis is placed upon Rhetoric and Speech. The emphasis is not upon these as formal courses but upon the transfer of thought clearly in presenting both written and spoken ideas to those who are not trained to understand the technical analysis or the technical vocabulary. In carrying out such a plan, only the third and fourth years of a college course can be specialized and even then only to a partial degree. At least 30 per cent of a student's total time in college should be devoted to the specific study of illuminating engineering to prepare him for apprenticeship in the profession.

A listing of some of the specific studies are indicated below, the first four being of direct technical nature while the remaining represent related subjects necessary for an understanding of the practice of illuminating engineering.

1. OPTICS — This course deals with the properties of light and the light phenomena. The basic principles of

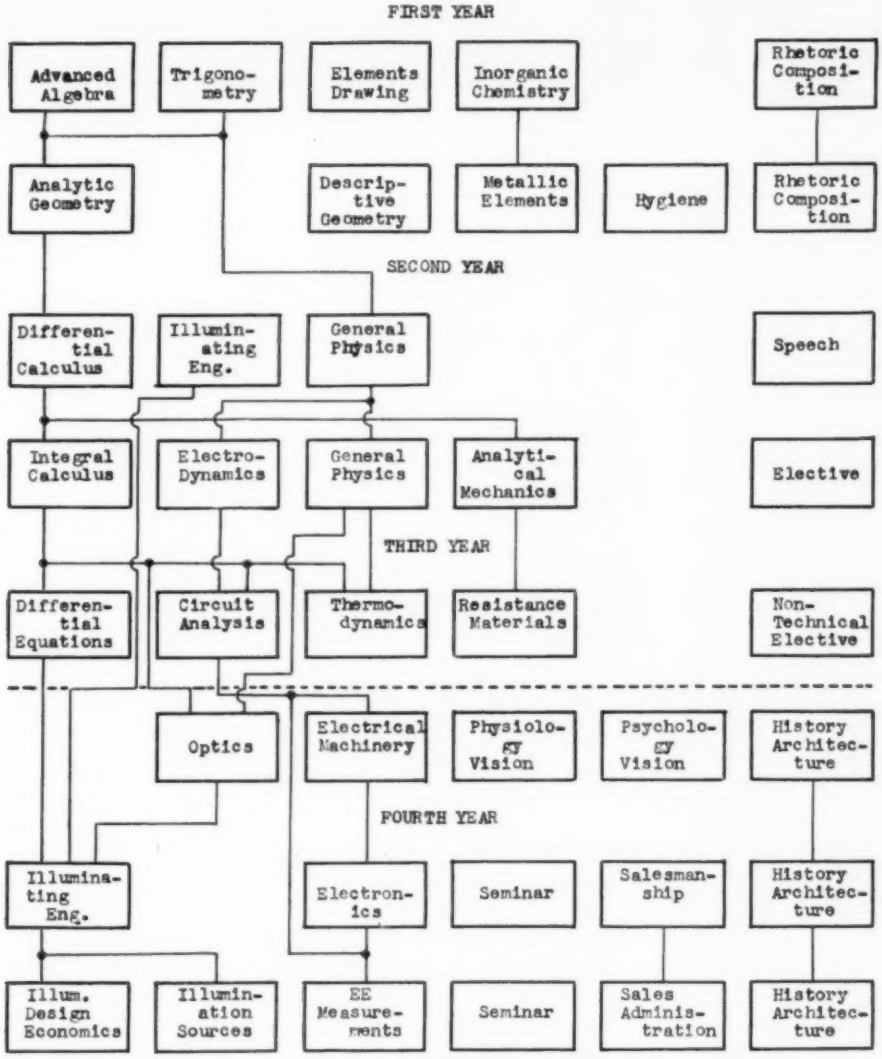


Figure 1. Illuminating Engineering Option at the University of Illinois.

optical instruments and devices are covered with consideration given to conduction in gases, radiation and photometry.

2. ILLUMINATION CALCULATIONS — It is essential that the student have a thorough understanding of the fundamental definitions and quantities in the subject and how these are interrelated. With the fundamental material as a background the testing and use of test data in illumination calculations for symmetrical and asymmetrical light sources are considered. The final steps cover the line sources, surface sources and enclosures, also the different methods of approach in the solution of these problems. A study of these approaches indicates the advantages of each method and its limitation and forms a nucleus from which the student can develop his own methods in treating illumination problems.

3. ILLUMINATION DESIGN—No engineering course is complete without a consideration of design. Design is confined to the equipment and the installation. The development of the use of equipment in lighting is marked by a study of the multi-source arrangement as contrasted with Illumination Calculation, where the work is confined to the individual unit as to flux and illumination distribution. In this course the economics of lighting installations and maintenance is given considerable study.

4. Sources — The study of the light source is divided into that which deals with the theory of the source and the source in use. The basic physics of line spectra and black body radiators forms the foundation upon which the actual operation of the source is based. Consideration is given to the electrical characteristics of the light sources in the electric circuit and devices used for better operation and operating characteristics.

5. Physiology of Vision — This considers the anatomy and function of the eye as of major importance with the association of the other senses and the physical structure of the body as reacting to the normal and abnormal performance of the seeing sense. Material is introduced to acquaint the student with methods of vision correction and methods of measurement which determine decrease or loss of the visual function under conditions of disease and fatigue. This material is not all given in the basic physiology course but is added throughout the complete organized curriculum.

6. Psychology of Vision — The human behavior in seeing is important in the determination of the comfort and advertising values of a lighting installation. Again it is essential to associate this one functional reaction to the other senses and the complete human psychology. Here as in physiology the basic material is given in a definite course, however, pertinent information in this field is introduced even in the technical portion of the training.

7. History of Architecture — Formal classes in the history of architecture give the student a background of the development of the various forms of architecture. The student develops in the vocabulary of the architect, follows his method of reasoning and is brought to an understanding that in the field of design the architect has definite reasons for demanding certain conditions because of the atmosphere he must create. It is desired, in such a course, that the illuminating engineer appreciate the point of view of the others with whom he must work in developing a comfortable and harmonious lighting installation.

8. Salesmanship — Since many of the students in illuminating engineering look forward to a career in the engineering sales field the principles of salesmanship are of vital interest. The thought behind such a course goes beyond the idea of practical information to the principle that an Illuminating Engineer has as a major part of his problem the sale of the idea of good and comfortable lighting, not only to the architect but frequently to the client. The principles of selling need not be applied to a product of manufacture alone but work equally well for the advancement of an idea.

9. Sales Administration — Since the tie between engineering and sales in Illuminating Engineering is so strong it is deemed advisable to equip the student with the principles and vocabulary of sales administration. Also a large number of those selecting the option have a marked interest in the sales division of engineering.

10. Seminar — A course in the preparation and presentation of technical papers. The illumination option students select topics in their field and thereby study intensively some small subdivision of the subject.

It is because of a criticism that Illuminating Engineering cannot be classified as a profession, that the educational institution has a major interest in the professional development of the Society and for this reason it has been thought best to discuss in one paper the question of professional standing and educational procedure in training Illuminating Engineers.

Society members have encouraged the establishment of an Illumination Option at the University of Illinois and the Chicago Section has supported the Option by establishing two scholarships, one at junior and another at senior level for individuals registered in Illuminating Engineering, for those showing both high scholastic standing and promise of future development in the profession.

With almost as many night games scheduled this past season as day games, the lighting of baseball parks has become a matter of major importance to this field of sports. At Fenway Park, Boston, the game shown here was played under lighting levels approaching daylight conditions. Minimum in the outfield was 200 foot-candles. Photo courtesy of the Boston Edison Co., through the Electric Institute of Boston, Inc.

Lighting a Large Office

LIGHTING OBJECTIVE: To provide suitable illumination for a variety of office tasks using low-brightness fluorescent lamps.

Installation at Lower Hudson District Office, Central Hudson Gas and Electric Corporation, Newburgh, New York

General Information: In lieu of windows the warm grey walls of this 1900 square foot office area are enhanced by panels of colorful wallpaper. The following table shows the surface characteristics of the area:

Ceiling	— black and white mottled Acoustone F	— 72 per cent RF	
Wall	— warm grey	— 72 " " "	
Wallpaper	— multicolor	— 45 " " "	(average)
Dado	— French grey	— 40 " " "	
Floor	— medium light grey linoleum	— 5 " " "	
Wheeldex tops	— tan linoleum	— 15 " " "	
Table tops	— tan linoleum	— 11 " " "	

(over)

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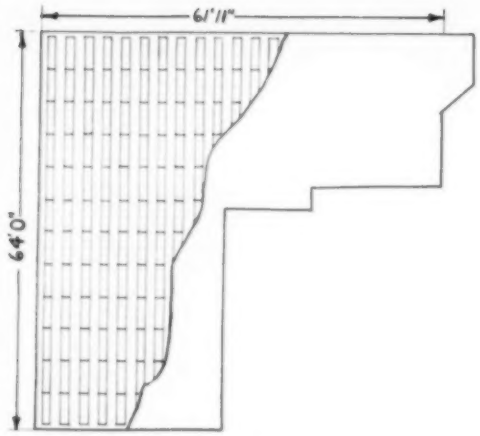
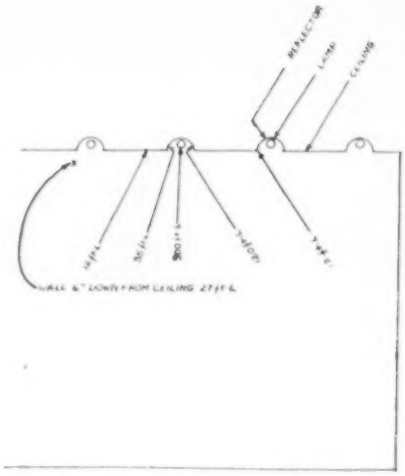


PLAN VIEW



Installation: An average illumination of 76 footcandles is provided by 178 40-watt T-17 4500K low-brightness fluorescent lamps mounted in Curtis No. 1762-C Alzak aluminum troffers on 30-inch centers. Luminaire brightnesses are shown in the sketch, and room brightnesses are indicated below:

Wall	— 24	footlamberts
Table tops	— 10	"
Wheeldex tops	— 13	"

Lighting data submitted by Taylor M. Barr, Central Hudson Gas and Electric Corp., Poughkeepsie, New York, as an illustration of good lighting practice and to aid in the design of similar installations.

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Series XIV 10-49

Development of a Gaseous Tube Directional Taxi-way Marker Light

By M. S. GILBERT

This report describes the development of a taxi-way marker light designed to indicate to pilots the exact location of the taxi-way without requiring a pilot to see more than one light of an installation at a time.

AT PRESENT most taxi-way marker lighting is accomplished by means of standard flush contact or runway lights modified by aviation blue glass color screens so that the unit appears to the pilot as a dim blue light regardless of the angle or position from which the light is observed. Thus, on a dark night or one with restricted visibility, a pilot taxiing his plane along a taxi-way using such lights, with their all-way type of distribution, can easily miss a turn in the pavement, and taxi the plane between a pair of lights on the same side of the taxi-way on to soft ground or mud. Such a mishap can have serious consequences or cause undesirable delay. Furthermore, the blue color screens are inherently inefficient, screening out and wasting much of the total generated light.

With the gaseous tube directional taxi-way marker light developed at the C.A.A. Experimental Station, it is proposed to use high current, relatively low voltage, blue fluorescent gaseous tube light sources installed to form a V-shape and so mounted in an elevated lighting fixture that the point of the V is always towards the taxi-way. Thus the pilot will always have a definite indication as to the location of the taxi-way.

MR. GILBERT is with the Civil Aeronautics Administration, Experimental Station, Indianapolis, Indiana.

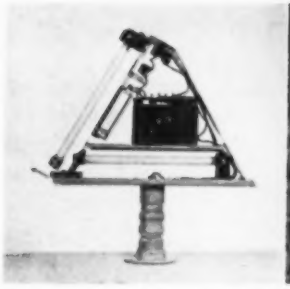
Twenty of these lights have been installed at Weir Cook Municipal Airport, Indianapolis, Indiana. Operating an average of 12 hours per night, the entire system will consume approximately 10 kwh per night, or in the neighborhood of 30 cents worth of electrical energy per 12-hour period.

The light consists of an elevated unit which stands 21 inches high, has plexiglass windows, and is provided with a frangible base coupling, disconnecting plug and switch. The operation of the latter is governed by the one-piece top, removal of which opens the switch.

Preliminary tests and observations indicate that the light can be readily recognized. Due to their flexibility of structure, when these units are struck by planes, they usually suffer only fractured couplings, broken lamps and some dents. A number of these, carelessly damaged by small planes parked near the taxi strip were straightened out and put back into service. No damage to the small planes

Figure 1. (Below) Gaseous tube directional taxi-way marker light.

Figure 2. (Right) Plowing in cable for taxi-way lighting installation.



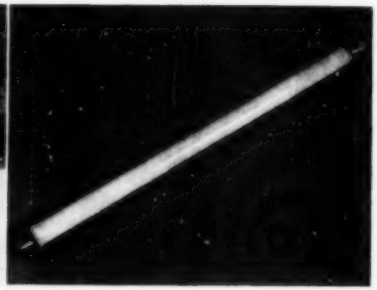


Figure 3. (Left) Taxi-way marker light (cover removed). Figure 4. (Center) Taxi-way marker light (uncoupled to show disconnecting plug). Figure 5. (Right) Lamp or tube for taxi-way marker light.

was reported. There were 11 cases reported of lights being hit before one cover was damaged too badly to be straightened out. This matter of breakage is particularly vexing at Indianapolis as many small planes are parked along the taxi strip. Such parking is not a general practice over the country.

Equipment and Installation

After observation of the continued economical and successful performance of relatively high current low voltage gaseous tubes in an experimental boundary lighting system at Aretz Airport, Lafayette, Indiana,[1] it was decided to use the same type of gaseous tube for an experimental taxi-way lighting system.

Consequently a development contract was negotiated with the tube designers, an independent manufacturing firm. Under terms of this contract the government was furnished 20 of the gaseous tube taxi-way lights complete with tubes and ready for operation (Fig. 1).

A 120-volt multiple distribution system was selected for supplying power to these units, as they are so designed that a relatively wide variation in voltage due to line drop has little effect on the operation. The installation was made with No. 10 and No. 12, 600-volt single-conductor trenchwire plowed in with a cable plow (Fig. 2).

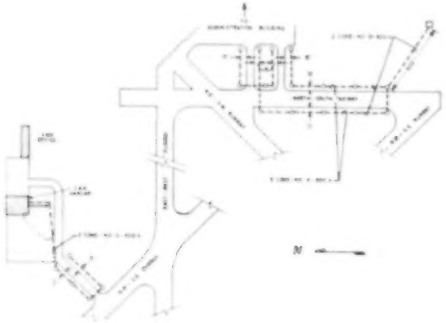


Figure 6. Wiring diagram and layout of experimental taxi-way lighting installation.

The lighting unit shown in Fig. 3 with cover removed, consists of a transformer, fuse block, capacitor for correcting the power factor, safety switch and blue gas-filled tubular light sources which are held in place by fuse clips. The component parts are mounted on a frame-work which is protected by a removable one-piece cover with plexiglass windows. Removal of this cover operates a switch to open the circuit to the transformer during maintenance. The windows are held in place by means of a self-sealing weather-strip.

A polarized plug and receptacle are enclosed in the fracture coupling so that if the unit is struck and knocked off the base, the electrical circuit will be disconnected at the same time without any live high voltage wires left hanging loosely. See Fig. 4.

Reflectors were originally provided with these lights, but tests showed that with these the effect was that of a lighted area rather than that of a bent line. After the reflectors were removed, the desired sharp, clearly-defined V-appearance resulted.

Although some question has been raised as to whether or not the units could be a little less bright for better results, nothing is being done to reduce the brightness until comments have been received from more pilots. No difficult problem is involved in reducing the brightness if such action is found to be necessary.

The lamp, or tube, shown in Fig. 5, which is designed for cold cathode operation, is made of lead glass, 20 mm diameter.

The interior of the tube is coated with blue

[1]Gilbert, M. S., "A Low Cost Boundary Lighting System for Small Airports," Technical Development Report No. 53, December 1946.

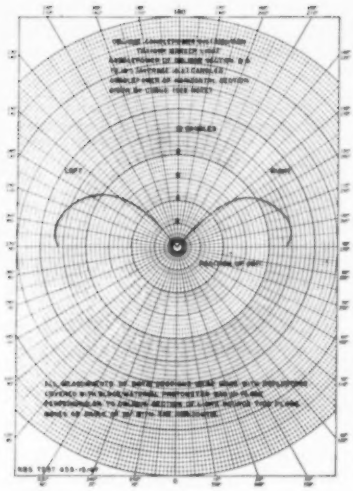


Figure 7. Cablepower distribution curve for directional taxi-way marker light.

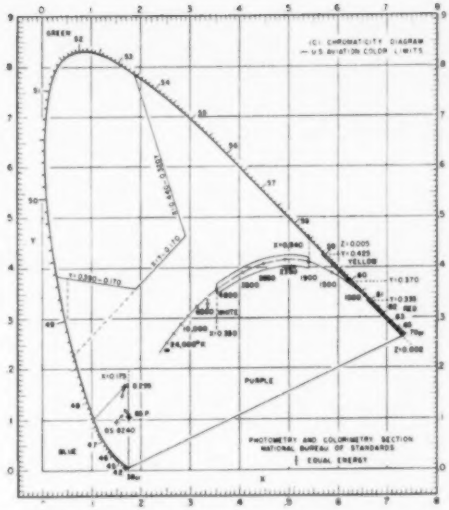


Figure 8. ICI chromaticity diagram for taxi-way marker light.

calcium tungstate fluorescent phosphor. At each end are the tungsten filaments which serve as the electrodes. These are especially designed for the desired current characteristics of the tube. During the manufacturing process the tube is exhausted and filled with argon gas at low pressure. To this is added a small amount of mercury which provides the proper spectral radiation for energizing the phosphor.

The current consumption of each lamp is 105 milliamperes and normal operating voltage is 95. In starting the lamp less than 500 volts are required.

The transformer is rated at 50 volt-amperes and consumes 0.45 amperes at 115 volts. Both 110-volt and 220-volt primary taps are provided.

An 8 mfd. condenser is connected across the transformer to correct the power factor to 85 per cent plus.

Tests made at the National Bureau of Standards show the bare tube to have a brightness of approximately 5 candles, for a 6-inch length. Candlepower of the unit is somewhat higher, as shown in the curve, Fig. 7.

The color of the lamp is within the specified requirements for aviation blue. (See Fig. 8.)

The units were spaced approximately 200 feet apart, some 10 feet from the pavement and some (where the taxi access strips are very narrow) approximately 15 feet away from the pavement. A sketch showing the location of the lighting units and wire is shown in Fig. 6.

Operating Costs

The operating cost of these taxi-way lights is very low as the power consumption of the individual unit is approximately 44 watts. At the present writing the lights have been operating 12 hours nightly for approximately 60 nights or about 720 hours without any burn-outs. No data is yet available on the life of the tubes, but it is estimated that they will continue to operate for well over 3000 hours without burn-outs. Result of life tests and production costs will of course determine lamp maintenance costs. Such costs should not prove excessive.

Conclusion

In view of the results obtained with this experimental type of taxi-way lighting, gaseous tube directional taxi-way lights should be seriously considered for future use on large airports.

They have been easily seen and interpreted by various pilots and are being received with enthusiasm by the airline pilots so far reporting.

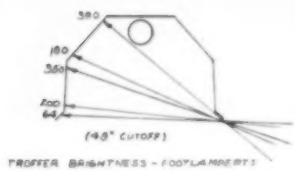
It has been found that these lights clearly point out the location of the runway and by the nature of their design make it possible to use a pattern of lights requiring fewer units than under the present standard practice.

While experience with this new type of taxi-way light will help in developing a satisfactory pattern, increased production should help in reducing the costs, so that both first cost and maintenance are expected to be well within the budgetary capacity of any airports requiring their use.

Lighting of Spinning Frames (Mules)

LIGHTING OBJECTIVE: To provide general illumination sufficient in quantity and uniformity for rapid detection and repair of broken threads.

Installation at the Bachmann Uxbridge Worsted Corp., Uxbridge, Mass.



General Information: The large industrial area shown in the photograph has a light cream ceiling (74 per cent reflectance) and a varnished maple floor (35 per cent reflectance).

Installation: Continuous rows of single-lamp porcelain enameled troffers (Miller Co. No. AC-1192) on 6'6" centers, mounted 10'6" above the floor, and equipped with 40-watt 3500K fluorescent lamps provide a maintained illumination of 35 footcandles. The brightnesses of the luminaire are indicated on the sketch.

Lighting data submitted by the Bachmann Uxbridge Worsted Corp., Uxbridge, Mass., as one solution of a lighting problem and to aid in the design of similar installations.

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Measuring Shadow and Diffusion with the Photoelectric Meter

By KONRAD NORDEN

IN A CHAPTER of my recent book on "Shadow and Diffusion in Illuminating Engineering,"[1] I have dealt with the part played by semi-shadows and have devised methods for calculating and measuring them. Since the measurements are made with the footcandle meter, the size of its photo-electric cell represents the area over which the shadows are measured. As a rule, the cell surface is small in comparison to the shadowed field so that unshaded illumination is not likely to be included in the measurement. On the other hand, ever-present semi-shadows will extend far beyond the surface area of any conventional cell, so that cells of different size may give different results inasmuch as they include more or less of the variable semi-shadowed field.

In a paper read at the 1946 Convention of the British I.E.S. on "Fluorescent Lighting Practice," Mr. W. J. Jones suggested that—

> While dealing with industrial applications it is not inappropriate to refer to the shadow characteristics or the opposite expression, diffusion characteristics of fluorescent lighting.[2]

and reported a series of very instructive tests. He did not specify the kind of cell used, but according to a private communication to the writer, he provided a small rectangular cell of approximately 40 x 19 mm, with a view to "keeping the depth of shadow practically uniform over the measuring surface," in other words, to eliminating semi-shadows, which, however, is easier said than accomplished.

Whether one should use a smaller or larger cell, evidently depends on the influence which the variation of the cell area has upon the result. In the present paper, I propose to determine this influence and draw certain conclusions therefrom. Before tackling the problem proper, I shall summarize the principle of the measuring method itself.

Fundamentals

The characteristic expression of shadow is the "Shadow Factor,"[3] approved and recommended by the Ninth Session of the I.C.I., defined as

$$S = \frac{E - E_r}{E}, \text{ where}$$

E represents the total unshaded illumination,

E_r the residue illumination in the shadow,

either quantity being measurable by means of a conventional footcandle meter.

The complementary term

$$D = 1 - S = \frac{E_r}{E}$$

represents the "Diffusion Factor."

In the simplest form of diagram, Fig. 1, L represents the light source whose flux towards P would produce at that point a shadowless illumination E, but is fully intercepted by shadow caster d, so that E_r becomes $= 0$, hence $S = 1$ and $D = 0$. Now, in good lighting practice exposed point sources are generally out of use, therefore Fig. 1 must be replaced by Fig. 2, where a surface light is indicated by line A_1B_1 representing either the diameter of a globe or bowl of a circular or the length of a linear source (luminous tube). Here caster d intercepts only the part of the flux emanating towards P from zone a_1b_1, which would result in total shadow at P were it not for the flux from zone $A_1a_1 - b_1B_1$, which freely passing by the caster hits P and illuminates that shadow up to a certain value $E_r < E$. The latter effect would likewise be produced by another light source located outside angle $2x$ which the caster subtends at P. For simplicity's sake, however, we shall not consider any additional sources, since for the purpose of this investigation, they do not afford novel features.

Still, even Fig. 2 does not represent the true story. What we measure with the footcandle meter is not the illumination of a point but of an area, *viz.* that of the photo-electric cell surface. We, therefore, must turn to Fig. 3, which is the

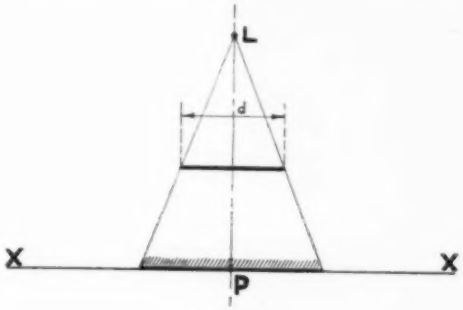

Figure 1.

Author: Sudeletro S. A., Rio de Janeiro, Brazil.

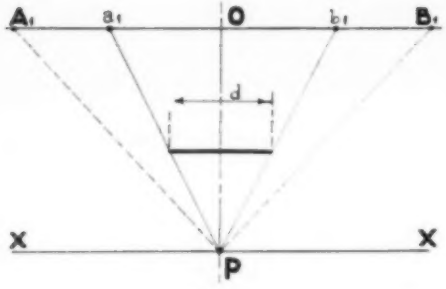

Figure 2.

fundamental diagram of practical shadow conditions. The area of the cell is indicated by F. Again we have a zone ab of the source — although not equal in size to the corresponding a_1b_1 of Fig. 2 — whose flux towards F is completely intercepted by caster d; the remainder of the source, however, behaves differently from that of Fig. 2. Only the flux from the outer zone $A_1A - BB_1$ passes completely by caster d and, inasmuch as it strikes F illuminates the full shadow caused by the obstruction of ab. There is, however, the flux emanating from the intermediate zone $Aa - bB$ towards F, which partly passes by the caster and hits a certain portion of area F, partly hits the caster and is intercepted. This zone is responsible for the formation of semi-shadows which are gradated from center to edge of F as the proportion of the intercepted and non-intercepted flux varies from one end of the zone to the other. Thus, if F now is to represent the sensitive surface of the photo-cell, the meter has to indicate not a uniform value E_r, but an average value $(E_r)_m$ over the semi-shadow due to zone $Aa - bB$, possibly superposed by a uniform component due to a farther zone $A_1A - BB_1$, if the source should extend beyond AB. Zone $A_1A - BB_1$ obviously plays the same part as an additional light source discussed in connection with Fig. 2, therefore needs not be considered for the purpose of this analysis.

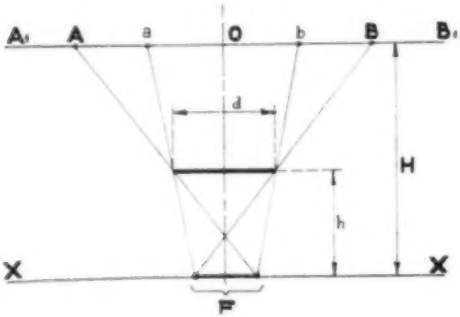

Figure 3.

Thus the task of determining the numerator of the shadow or diffusion factor comes to measuring $(E_r)_m$ over the gradated semi-shadow due to zone $Aa - bB$.

Now, if we have two footcandle meters, one with a smaller, the other with a larger photo-electric cell, calibrated as they should be so as to give equal readings in response to any given unshaded illumination E, their readings must differ in the case of a gradated semi-shadow inasmuch as the flux striking the excess surface of the larger cell differs from the mean flux striking the smaller cell. Our problem is now to find out what this difference amounts to at its most, *i.e.* when comparing the smallest cell practically used for ft-c measurements with the largest one.

Photo-Electric Cells

The photo-electric cells used by the various manufacturers of footcandle meters differ in shape and also in size. Insofar as we deal with circular shadow casters, cells fit for shadow measurements should be circular. The commonly used types 614 and 703 of the Weston Sight Meter are equipped with a circular cell of $1\frac{1}{2}$" — 38.1 mm in diameter. Another Weston type, No. 603, having two such cells mounted in a pad, is not suitable for shadow tests. The same is true of the General Electric meter owing to the rectangular shape of its cell. The Westinghouse meter is similar to the Weston 703 in cell area, however not quite circular, therefore only of limited use for our purpose. In England, Everett Edgcumbe & Co. Ltd. make much used footcandle meters, supplied also by the Holophane Ltd. under the latter's trade name, with circular cells of 45 and 67 mm in diameter. German manufacturers before the war employed with their "Luxmeters" circular cells of 35 and 57 mm.

Among this variety the largest cell is that of 67 mm. When looking for the smallest, we must remember that some manufacturers supply with their meters diaphragms called "Multiplier Disks" for amplifying the scale of the instrument at a ratio of 1:10 by reducing the cell surface to a tenth of the normal. The Weston cell of 38.1 mm when covered by the disk with six small openings of about 5 mm each, thus becomes equivalent to a cell of 12 mm in diameter. There is, in fact, no limit to which the reduction may not be carried; even for point-to-point measurements of illumination has the photo-electric cell already been adapted.[4] We are, therefore, not very far from reality if we take as the lower limit a theoretical cell of point size.

Our problem thus practically narrows down to this: we have to determine once E and $(E_r)_m$ with a cell of 67 mm (cell No. 1), then E and E_r with a

cell of point size (cell No. II). The divergence of the resultant quotients $\frac{E_r}{E}$ gives us the maximum divergence likely to occur in practical diffusion tests.

The Test Case

As a test case, we take the illumination of a work bench produced by a fluorescent tube AB (Fig. 3) horizontally suspended at a height H above the working plane. The numerical value of H can be fixed arbitrarily; not so, however, the numerical data of the shadow caster, *viz.* its height h and diameter d, upon which depends the width and location of the semi-shadow producing zone $Aa - bB$, hence the value of $(E_r)_m$. The width of this zone is entirely independent of d, depending exclusively upon $\frac{h}{H}$ or, once H is fixed, increasing with h, though not quite proportionately. On the other hand, as d is increased while h kept constant, the zone of constant width is shifted towards the ends of the light source.[5]

We settle on a case where zone $Aa - b$B occupies the greater portion of AB, adopting for convenience certain data of an example already analyzed in my book. These data are —

$AB = 1192.6$ mm (approximately the length of a 48" tube)
$H = 1219$ mm or 4'
$d = 88$ mm
$h = 150$ mm

Under these conditions, the semi-shadow producing zone $Aa - bB$ becomes = 955.6 mm, which is 80 per cent of the full tube length. A shadow caster of these data simulates a man's hand at a level of 150 mm above the plane of work.[6] The case is diagrammatically (not to scale) represented by Fig. 3 with cell I indicated by F, and by Fig. 4 with cell II indicated by P. We now have to determine the numerical value of D_{I} from Fig. 3 and D_{II} from Fig 4.

By comparing the two figures, we note that zone $aA - bB$ of Fig. 3 has ceased to produce semi-shadow in Fig. 4 where half of it has accrued to the full shadow producing zone now increased from ab to $a'b'$ (the latter, by the way, identical with a_1b_1 of the former Fig. 2), and the other half turned into an unobstructed zone whose total flux emitted towards P illuminates that point. Our result, therefore, depends on how much the semi-shadow producing flux due to the entire zone $Aa - bB$ (Fig. 3) differs from the unobstructed flux due to its half $Aa' - b'B$ (Fig. 4).

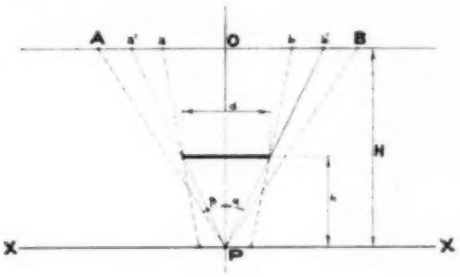

Figure 4.

The Method

Prima facie one should assume that the simplest way of settling the matter would be by experiment, *i.e.* building up the test case and taking the above measurements. However, even provided that specimens of cells I and II were readily available, their inherent errors might obscure the very divergence we are trying to determine; one should also bear in mind that the magnitude of error stated by the maker of the instrument refers to a more or less uniform and not to a gradated illumination, so that new problems would arise when assessing the readings.

All this can be avoided and fully reliable values of D_{I} and D_{II} obtained by way of *calculating* them. The only postulate is that the tubular lamp AB must be treated as a pure line source; as the essential factor in semi-shadow formation is the length rather than the width of the source, there is no reason why the results thus derived should not equally apply to an operative fluorescent lamp.

The calculation of E and E_r for cell II, Fig. 4, is based on the well known formula for the illumination of a point perpendicularly beneath the center of a line source, *viz.*

$$(1) \quad E_{\text{II}} = \frac{B}{2H}\,(2\beta + \sin 2\beta)$$

where B represents the brightness of the lamp and 2β the angle subtending its length AB.

This formula, by the way, has originally been derived and published by the author as early as in 1908.[7]

From Equation (1) follows, if $2x$ denotes the angle subtending $a'b'$, Fig. 4 (same as a_1b_1, Fig. 2),

$$(2) \quad (E_r)_{\text{II}} = \frac{B}{2H}\,[2\beta + \sin 2\beta - (2x + \sin 2x)]$$

hence

$$(3) \quad D_{\text{II}} = \frac{E_r}{E} = \frac{2\beta + \sin 2\beta - (2x + \sin 2x)}{2\beta + \sin 2\beta},$$

eliminating B and H.

The calculation for cell I, Fig. 3, is not so easy. The illumination of a circular area by a line source is too complicated a function to be expressed by a plain formula, therefore one has first to compute differential fluxes due to elements of the line source, using a formula derived by Lambert for

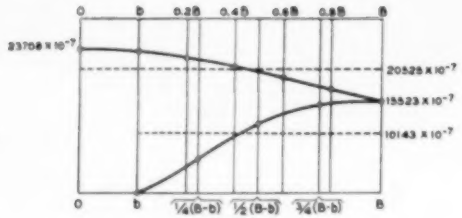

Figure 5.

the fluxes exchanged between a luminous element ε and a circular area, *viz.*

$$(4)\quad \varphi_\varepsilon = \tfrac{1}{2}\pi \left[1 - \frac{H^2 + r^2 - \frac{f^2}{4}}{\sqrt{\left(H^2 + r^2 - \frac{f^2}{4}\right)^2 - r^2 f^2}} \right]$$

where f is the diameter of our area F, and r the distance of its center from the point perpendicular beneath ε, in Fig 3 being OB. In order to obtain the total flux $\Phi = \int \varphi_\varepsilon d\varepsilon$ of the source striking F, we must compute from (4) a number of fluxes for various positions of ε, plot the results according to curve "A" in Fig. 5 with the fluxes φ_ε as ordinates and the central distances of the elements ε as abscissae, then obtain the mean value of the fluxes and multiply it by the total length AB of the source. In the illustration only half of the source, from O to B, is represented, the other half being symmetrical.

So far so good regarding the unobstructed flux Φ. For the partly intercepted flux Φ', however, existing lighting calculations do not afford any serviceable formula. We use the new method developed by the author, the description of which would exceed the scope of this paper and will be found, together with an example of its application, in the author's above-mentioned book. The calculation is to be made for various elements ε of the semi-shadow producing zone $Aa - bB$ of the source, the results plotted and recorded in curve "B," Fig. 5, and the mean value of the fluxes multiplied by the length of the zone. As final result we get $D = \dfrac{\Phi'}{\Phi}$ for cell I.

Numerical Results

Cell I (67 mm)

Curve "A," Fig. 5, gives a mean value $(\varphi_\varepsilon)_m = 0.0020525$; multiplying by $AB = 1192.6$ mm we get

$$\Phi = 0.2449$$

Curve "B" gives a mean value $(\varphi'_\varepsilon)_m = 0.0010143$; multiplying by the length $Aa - bB = 955.6$ mm, we get

$$\Phi' = 0.09687$$

hence $$D_{\mathrm{I}} = \frac{0.09687}{0.2449} = 0.3955$$

Cell II (point size)

Equation (1) gives

$$E_{\mathrm{II}} = 0.006970$$

Equation (2) gives

$$(E_r)_{\mathrm{II}} = 0.006970 - 0.004556 = 0.002414$$

hence $$D_{\mathrm{II}} = \frac{0.002414}{0.006970} = 0.3460$$

and the variation $$\frac{D_{\mathrm{I}} - D_{\mathrm{II}}}{D_{\mathrm{II}}} = 0.125$$ or

D_{II} 12.5% lower than D_{I}.

To check this result, I quote from my book the example analyzed therein which offers similar conditions of light source and shadow caster, however, a cell of intermediate size between I and II, *viz.* the Weston cell of 38.1 mm in diameter. In that instance the variation amounts to

$$\frac{0.257 - 0.242}{0.242} = 6.2\%$$

which fits very well into our picture. (The higher value quoted in the footnote on page 97 of the book must be corrected accordingly.)

Synopsis and Conclusions

Measuring the residue illumination of shadows with the footcandle meter amounts to measuring the average illumination over a semi-shadowed area defined by the size of the sensitive surface of the cell. Thus, different results obtained with cells of different size under equal conditions of light source and caster, denote that the shadow or diffusion factor varies with the area over which it is determined. Should this variation be considerable, we would have to agree upon a standard size of cell for measuring S or D factors.

Between extreme limits this variation has been found amounting to 12.5 per cent. In assessing this result we must take into account that for simplicity's sake we have neglected any unobstructed fluxes whether due to an extension of the source beyond AB or to additional light sources, although either will be present in almost every practical illumination. Assuming, *e.g.*, that unobstructed fluxes will increase the unshaded values of Φ and E_{II} respectively by 50 per cent, it is easy to ascertain that the variation will then be reduced to 5.85 per cent; or, if the increase be 100 per cent, farther down to 3.65 per cent; either value being already within the inherent error of the instrument.

Consequently, when determining shadow or diffusion factors in a practical installation, it is irrelevant which of the conventional footcandle meters may be employed.

A further conclusion can be drawn from the above values with respect to calculating shadow factors in *illumination design*. The exact method, of course, is that used above in connection with cell I, but is much too cumbersome for engineering practice. For this purpose sufficient accuracy will evidently be obtained by the simpler method used with respect to cell II, *viz.* substituting for the shadowed area its central point and calculating D after equation (3).

Another category of shadow measurements is that intended to reveal the inherent light-diffusing qualities of an isolated source (lamp or luminaire), with a view to comparing different types of sources as to their diffusing effect. These tests must be made under identical conditions, *i.e.* with a standard caster in a well defined test room at a certain mounting height.[8] Since additional sources do not exist, we cannot count on the reducing effect of unobstructed fluxes, therefore the size of the cell becomes relevant to tests of this category. Considering that larger cells will bring out better the diffusion characteristics of the source, we ought to keep to the upper range of conventional cell sizes. Thus by using no smaller than the Weston 38.1 mm cell we can limit the possible variation to the admissible rate of $12.5 - 6.2 = 6.3$ per cent.

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5. Norden, Konrad: "Shadow and Semi-Shadow," l.c.[4].
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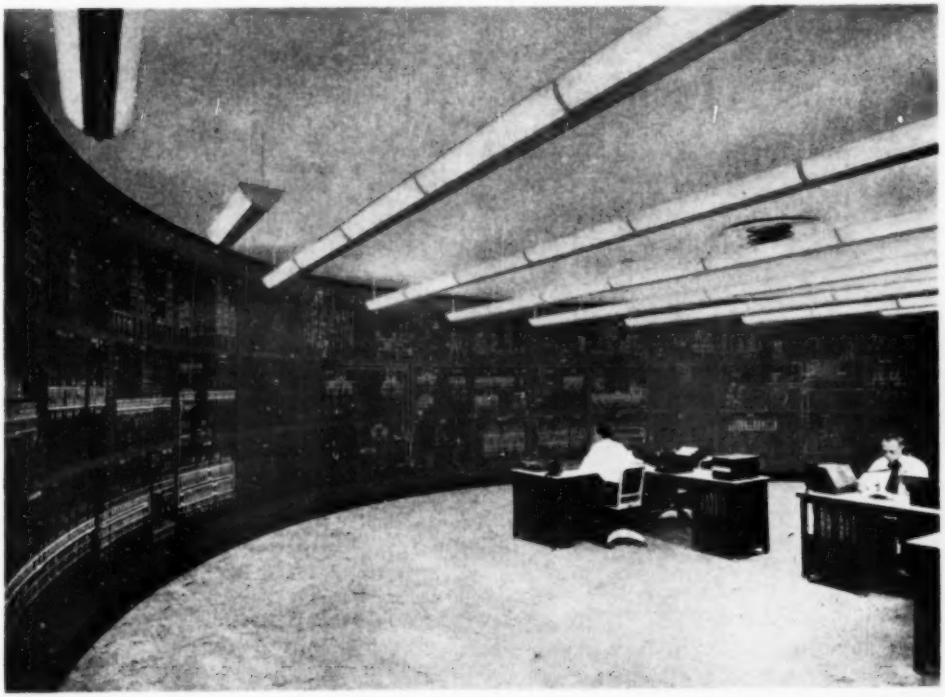
7. Norden, Konrad: "Beleuchtungsberechnungen fur Quecksilberdampflampen," *Electrotechnische Zeitschrift*, 1908, Heft 37.
8. Norden, Konrad, l.c.[3], p. 124.



Latest Thinking on Nerve Centers — A great deal of study, research and engineering went into the design of this "nerve center" — the load dispatching room of the Consolidated Gas Electric Light & Power Co. of Baltimore, Maryland. Fluorescent fixtures mounted on a 10-foot mounting height from an 11-foot ceiling in continuous rows spaced on 5½-foot centers, provide approximately 50 footcandles of comfortable, glareless indirect illumination. Planned Lighting by the Edwin F. Guth Co., lighting design by H. M. White, Consolidated Gas Electric Light & Power Co., Baltimore.

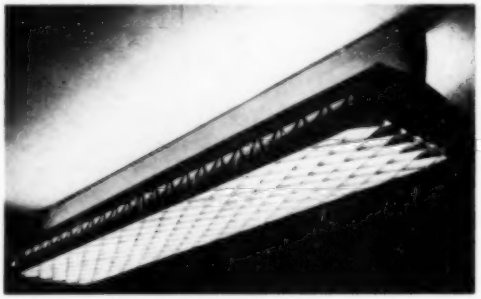
Lighting Techniques in the Rebuilt Rotterdamsche Bank

By L. C. KALFF

ONE OF THE first reconstruction jobs to be completed after the war in badly-damaged Rotterdam was the rebuilding of the head offices of the Rotterdamsche Bank. Destroyed by bombing in 1940, together with the entire center of Rotterdam, rebuilding plans were considered an opportunity for the application of many new ideas on a large scale, and especially in the lighting systems.

In the rebuilding of the Rotterdamsche Bank, the architect, Dr. H. F. Mertens, and his advisors, were faced with the difficult task of planning for this large building (180,000 square feet of floor space) all sorts of technical devices for heating, air-conditioning, acoustics, etc., not the least of which was the lighting. In spite of the country being practically isolated by five years of German occupation, they had to try to make the projects so progressive as to be modern by the time they could be realized. This was admittedly quite a problem, especially as regards the lighting because the engineering developments for fluorescent lamps were just beginning.

In those days only the fluorescent lamps of 25 watts, with about a 1000-lumen output were being made in Holland, on a small scale at that, with a five-foot 3000-lumen lamp at that time in the planning stage.



One after another four projects were worked out for the lighting of the offices, each reflecting the stages of development in the years since 1942. The first prototype of a special louver-fitting as shown above gave the most promising results. The largest part of the ceiling was going to be used for panel heating, so the fixtures had to be mounted on the girders. Each fixture could contain one, two or three lamps; two-lamp systems so common today had not yet been developed.

For the whole building a 30-footcandle lighting level was accepted as the minimum, whilst for those rooms where more exacting visual tasks had to be performed, or where daylight was excluded, a level of 50 to 60 footcandles was deemed to be necessary.

Since lines of unscreened lamps are not desirable generally, it was decided to mount the fluorescent lamps in fittings. A logical solution would have been to mount the lamps in channels in the ceiling, but by the time preparations had reached that stage the ceilings had all been occupied by the installations for heating and ventilation.

IR. L. C. KALFF is General Art Director, Philips Works, Eindhoven (Holland).

1. Marble entry hall — 20 to 30 footcandles. Unit fixture blends effectively with hall decoration.

2. All metal fixture which can accommodate one, two or three 40-watt lamps. Can be used individually or in rows.

3. Vault access hall — 30 to 60 footcandles calculated. Illuminated by a cove and recessed louvered troffers.

4. Portion of general offices—about 50 footcandles on desks. Rows of 11 unit fixtures follow roof line.

In order to match the lighting installation as far as possible to the form of the interior a type of fitting was designed that could be mounted in continuous lines directly against the ceiling. Moreover, this would give not only sufficient direct lighting on the working plane but also a certain amount of indirect lighting from the ceiling and walls. To save costs it was arranged to have two or three lamps in each fitting. Finally, there was the scarcity of glass to be reckoned with, so that ultimately an all-metal fitting for this project was designed.

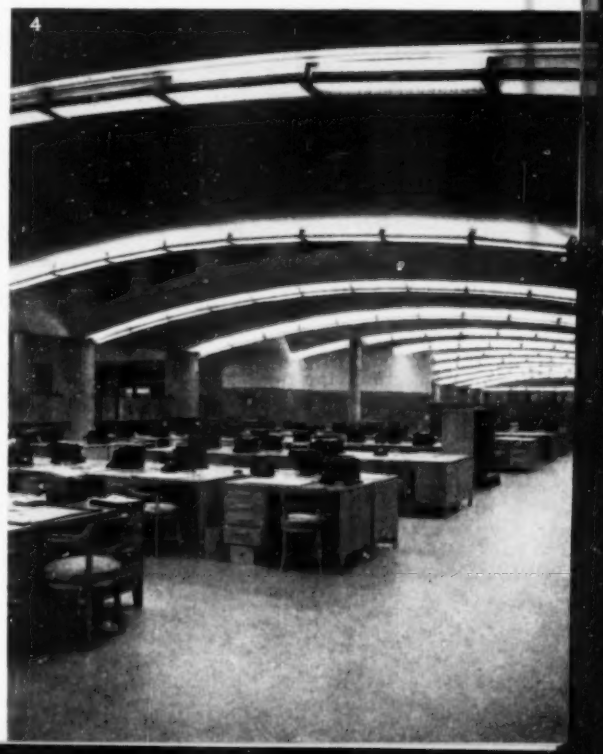
The fixture is made of sheet iron and in it can be used either one, two or three fluorescent 40-watt lamps. The mounting channel carrying the chokes and starters has been purposely made high so that the lamps hang far enough below the ceiling to throw some light upon it over a fairly wide area.

The lamps are screened underneath by metal louvers. Sections of this louver let the light through at an angle of at most 2 x 70° measured in the longitudinal axis of the lamp and under an angle of 2 x 60° laterally. These louvers which are nowadays used in all shapes and in different ways, leave a free passage for the light in the desired angles of emittance. They do not have the disadvantage of glass plates which in course of time lose their translucency owing to the accumulation of dust.

At the present time, when twin-starters can be used, an even number of lamps per fitting would be preferable, but at the time that this project was put into execution 1946) these twin-starters were not yet on the market.

In the offices units of two or three lamps were installed, so that in general it would be a fairly easy matter to use six lamps in three twin-combinations. For the sake of uniformity and in order to have the lighting installation in the general offices as far as possible conform with the architecture of the building the same type of fitting was used in the majority of the offices. A more decorative lighting was used only in the entrance-hall, in the safe-hall, the managers' rooms and the board-room.

It is with great satisfaction that today we can show a few photographs of this installation. In our opinion, it is comparable with some of the best installations in the world, especially when it is considered that it was designed and planned independently in a country completely isolated from those parts of the world where technical progress in the lighting field was still possible.



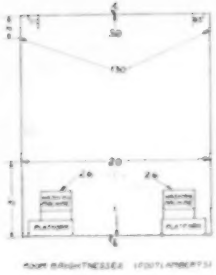
Lighting a Launderette

LIGHTING OBJECTIVE: To provide illumination of sufficient quantity and proper quality for operating automatic washers and for reading while waiting.

Installation at Launderette, 432 Main Street East, Rochester, N. Y.

General Information: The surface characteristics of this 44′ x 17′ x 13′8″ area are indicated below:

Ceiling	— white	— 80 per cent RF
Walls	— white	— 80 per cent RF
Platforms	— black	— 5 per cent RF
Floor	— marbleized black	— 1 per cent RF



FOOT BRIGHTNESSES

Installation: General illumination is supplied by two-lamp, 40-watt, 4500K bare fluorescent strip mounted around three sides of the room directly on the ceiling behind a valance (twenty four-foot lamps on each side and eight across the rear). This provides 65 footcandles at the machines and 40 footcandles on the chairs in the center of the room. Brightnesses are shown on the sketch.

Lighting designed by V. D. Mitchell, Rochester Gas and Electric Corp.; installed by P. R. Rause, 94 Locust St., Rochester, New York

Lighting data submitted by V. D. Mitchell, Rochester Gas and Electric Corp., 89 East Ave., Rochester, New York, as an illustration of good lighting practice and to aid in the design of similar installations.

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Lighting for Machining of Small Metal Parts

Prepared by the Committee on Lighting for the Machining of Small Metal Parts of the Illuminating Engineering Society

FOREWORD

Herewith is presented a revision of the 1939 report on "Lighting for the Machining of Small Metal Parts." (*Trans. I.E.S.*, January 1939, p. 21-54.) The revision is essentially the same as the previous treatment except for the addition (in Section 5) of material relating to fluorescent light sources. This report is not intended as a complete analysis of all of the seeing tasks encountered in the metal-working industries but as a study of some of the major and most exacting seeing tasks.

COMMITTEE ON LIGHTING FOR MACHINING OF SMALL METAL PARTS

J. M. SMITH
E. A. LINDSAY
W. H. KAHLER
R. E. MAUSK

1. Introduction

(a) In this work an earnest effort was made to abide by a definite technique such as is outlined below, and each visual problem was approached with this point in mind:

(1) What must be seen?

Observations were made to determine to what extent the operator is dependent upon seeing for the particular operations, to what extent his movements are necessitated, aided, or inhibited by his ease of seeing.

(2) How is it seen?

Observations were made to determine the detail that the operator attempts to recognize and how quantity and quality of *light* would affect this detail recognition.

(3) What quantity and quality of *lighting* will provide the most efficient, safe, and comfortable seeing conditions?

The quantity and quality of lighting should be defined by the result desired at the point of work rather than by description of the light-producing sources. This technical specification of the desirable lighting result should include the quantity, direction, degree of diffusion, shadow contrast, background contrast, maximum source brightness, spectral quality of light, and a description of all other modifying factors. Furthermore, this specification of the lighting result should not be influenced by present practice or the availability of equipment.

(b) The industrial plant* in which these studies were made is well lighted according to present-day practice. Machinery, ceilings, and walls are regularly painted and excellently maintained. The comments and observations of the operators were valuable and the work was carried on in an environment representative of the best of modern plant practice.

(c) After a careful survey of the plant is was decided to confine the study to representative major operations. These were found in the tool room and were the operation of machines such as lathes, grinders (internal, external and surface), millers (universal and vertical), shapers, drill presses, bench work and inspection of metal surfaces.

(d) The setting up and operation of these machines present similar seeing tasks. The precision of such machine operation usually depends upon the accuracy of the set-up and the careful use of the graduated feed indicating dials rather than the observation of the cutting tool or its path. The work is usually checked by portable measuring instruments and only in rare cases is a precision cut made to scribed line.

2. Fundamental Seeing Task

Analysis of the above operations disclosed a fundamental seeing problem, namely, *the discrimination of detail upon plane or curved metallic surfaces.* The visual tasks of seeing details on plane and curved specular and semi-specular metallic surfaces are severe but fortunately most cases are quite similar. These seeing tasks are distinguishing cut divisions on scales, micrometer calipers, dials, etc., scribe marks and indentations, blow holes or other surface defects.

*The Cleveland Graphite Bronze Company, Cleveland, Ohio.

3. Procedure of Study

3.1—General

(a) The Luckiesh-Moss Visibility Meter[1] was used to obtain an indication of relative visibility. In all of the tests discussed in this report, care was taken to hold constant all of the physical conditions of the test with the exception of the variable which was being studied. In order to establish a criterion for the use of the meter to compare the relative visibilities of three dimensional seeing tasks, the following tests were made. The illumination was varied by changing the source brightness.

(b) If the proper correction factors are applied, the visibilities are comparable and measurements can be made under any quantity of illumination, as is evident from a study of Table I. This was extremely useful as many readings were made in the factory to establish laboratory procedure. However, all data presented herewith were obtained under controlled laboratory conditions. It should be emphasized that throughout the report, visibility readings are to be considered indicative and not absolute.

3.2—Spectral Quality

To determine the effect of *spectral quality* of light upon the visibility of typical machine shop seeing tasks which had not been specifically covered by previous investigators,[2,3] relative visibility measurements were made on micrometer calipers, steel rules and on lines scribed upon a number of common surfaces, illuminated by mercury, tungsten and color-corrected (blue filter) tungsten light. However, as in previous investigations,[2,3] no significant differences in visibility were found.

[1] "Visibility—Its Measurement and Significance in Seeing," *Journal of the Franklin Institute*, October, 1935, page 459.

[2] "Seeing in Tungsten, Mercury and Sodium Lights," *Transactions I.E.S.*, July, 1936, page 655-674.

[3] "Comparison of the Light from the High-Intensity Mercury Vapor Lamps and Incandescent Filament Lamps for Visual Tasks," *Transactions I.E.S.*, April, 1937, page 365-378.

TABLE I.—Relative Visibility of Convex Scale Illuminated by Diffused Light
(Source of Large Area and Constant Position)

Illumination on Work	Relative Visibility as Read	Relative Visibility Corrected to a Common Footcandle Basis
10 Ft-c	3.55	3.55
20 Ft-c	4.70	3.45
50 Ft-c	9.0	3.70
100 Ft-c	16.0	3.60
Average		3.56

TABLE II.—Relative Visibility of Convex Cylindrical Scale Illuminated by Several Qualities of Lighting
(Ten footcandles on work in all cases)

Quality of Lighting	Angle Subtended by Source in Plane Normal to Axis of Cylinder (Source Angle in Degrees)	Relative Visibility
1. Direct Exposed Light Source—No Diffusion	1½	1.2
2. Direct—Open-type Industrial Reflector Equipped with White Bowl Lamp	14	1.2
3. Direct—Diffusing Industrial Reflector	20	1.2
4. Direct—Diffusing Industrial Reflector	36	1.5
5. Large Area—Low Brightness Source	100	4.0

TABLE III.—Relative Visibility of Convex Scale Illuminated by a Diffuse Source and an Extraneous Glare Source

Diffuse Source **subtended an angle of 90 degrees at the work.**
Extraneous Glare Source **(Open type Industrial Reflector) placed successively at eight locations on the periphery of a circle of 5 foot radius 5 feet above the work plane.**

Illumination on Work			Relative Visibility* (Corrected to a Common Footcandle Basis)
From Diffuse Source	From Glare Source	Total	
10	18	28	2.1
20	18	38	2.5
50	18	68	2.7
100	18	118	3.0

*Average of eight locations.

3.3—Quality

It was found that the *quality of lighting* was the most important factor in obtaining good visibility of the seeing tasks and comfortable seeing conditions. A preliminary study revealed that although the tool room was well lighted according to present-day accepted industrial standards, the men moved various seeing tasks (particularly micrometer calipers) about in an effort to avoid glare from specular reflection, often shielding the principal light source with their bodies or holding the task in a shadow. They apparently preferred a low value of diffused illumination to a greater quantity of direct lighting with its associated glare by reflection.

3.4—Visibility of Specific Seeing Tasks

3.4.1—*Convex Scale*

(a) A test was made of the visibility of a convex scale illuminated by various qualities of lighting. The micrometer caliper was selected for the initial experimental work, because of (1) its universal use in metal-working (2) its portability and (3) its similarity to the majority of the seeing tasks encountered.

(b) These results were confirmed by other experiments. From Table II it is evident that the best visibility (Fig. 1) was obtained when the source was of large-area and low-brightness whose specular reflection on the micrometer was a band of sufficient width to form a uniformly bright background for the figures and divisions which must be seen. High visibility was obtained because of the good contrast between the dark figures and the bright background as well as the lack of reflected glare. Although the same footcandles were available from the nearly point source, the appearance of the micrometer was vastly different. As shown in Fig. 2 the reflection of this source (#1 Table II) was a narrow brilliant (glaring) band which obscured the remainder of the micrometer because of the harsh specular reflection. The actual figures which were being read and their background were dark so that the brightness-contrast was very poor. These two factors resulted in low visibility.

(c) The physical characteristics of the source which is used will modify the effect.[4] Our laboratory observations, however, indicate that due to the relatively small size of the direct type of industrial reflectors in use for general lighting, essentially the same range of visibility will be obtained. (Fig. 3)

Investigations were then made of extraneous factors which would affect the visibility obtained from sources of large-area and low-brightness.

(d) It was found as indicated in Table III that a typical open-type industrial reflector in the vicinity reduced visibility to a considerable extent even though the principal component of illumination was supplied by the source of large-area and low-brightness. Increased diffuse illumination overcomes this glare to a great extent although the visibility does not increase to that obtained when the glare source is absent. (See #5 Table II)

(e) The visibility of the convex scale was then studied when illuminated by a source of constant brightness. The illumination upon the object was altered by changing the mounting height of the source. The variation in source angle, however, was not significant since in all cases the reflected image was of sufficient size to act as a background for the scale.

(f) Table IV indicates that for a source of given brightness, whose reflection forms the background of the detail to be seen, the visibility decreases as the actual illumination is increased.

(g) An explanation is that dirt and grease, etc., of an appreciable reflection factor have lodged within the cut detail. The brightness of this matte material increases in proportion to the illumination whereas the brightness of the background remains constant, being proportional to the source brightness. Contrast is lessened and consequently the visibility is decreased.

[4]The Influence of General Lighting on Machine Shop Tasks. *Trans. I.E.S.*, March 1939, pp. 271-296.

3.4.2.—*Steel Rule*

(a) To supplement the work described above on the convex scales, visibility measurements were made on a machinist's steel rule. This rule is typical of those found in machine shops.

(b) Relative visibility measurements were taken for the 1/64-inch divisions of this rule when illuminated by diffusing-type industrial reflectors, so situated that the scale reflected no image of the light source to the eye of the observer. The rule was then tilted slightly so that a portion of it was covered by the reflection of one of the lighting units. In addition, measurements were made using a directional beam of light from the observer's left and at an angle of 45° with the horizontal. Finally measurements were taken when the rule was illuminated by a source of large area and low brightness whose reflection covered the entire section of the scale which is of interest. A summary of these data is included in Table V.

(c) The maximum visibility occurred when the scale reflected the image of the light source to the observer's eye. This condition caused the cut divisions of the scale to appear as dark lines against a bright background. This is the ideal way to light a flat scale, providing it is of nearly uniform brightness over the entire section of the rule which is of interest to the operator.

(d) It should be noted from this table that the same visibility is obtained with equal source brightness regardless of the actual source. The seeing conditions in Case 2 are not truly indicated by the visibility readings since the rule is not uniformly bright and the reflection is likely to be glaring (Fig. 4).

3.4.3—*Scribed Marks*

(a) To further correlate the study of the effect between quality of illumination and visibility, numerous tests of relative visibility were made on scribed marks on various types of surfaces. Some of these data are included in Table VI.

(b) An examination of these data reveals several significant facts. When light of a directional characteristic[5] is used, good visibility of scribed marks may be obtained if the marks are oriented for maximum visibility (Fig. 6-A). This position is such that the brightness of the source is reflected from the side of the scribed marks to the observer's eye. The disadvantage of such a system is that poor visibility results for all scribed marks except those that are oriented for maximum visibility (Fig. 6-B).

(c) If the surface to be scribed is treated with a dye, which has a low reflection factor, the process of scribing will remove the dye, exposing the surface of the metal. If the piece is illuminated so that these lines appear bright against the darker treated background, good visibility is obtained for the scribed marks, regardless of their direction. This is indicated in Table VI, Item 3, under the large-area low-brightness source (Fig. 6-C).

(d) In the case of scribing on specular and diffuse aluminum a slightly different condition is found. Here the maximum visibility for scribing was found when these pieces were lighted so that the scribed marks appeared dark against a uniformly bright background. (Source of large area and low brightness).

(e) When there is considerable difference in the contrast between the scribed line and the background, the large-area, low-brightness light source accentuates this contrast and increases visibility. When there is little difference in the contrast between the scribed line and the background, directional lighting will heighten contrast, either by utilizing the difference in specular reflection between the scribed line and background or by the introduction of shadows.

TABLE IV.—Inverse Variation of Relative Visibility of Convex Scale with Respect to Illumination

Large area source of constant brightness.
Illumination increased by lowering source position.

Condition I			
Source Brightness = 90 footlamberts			
Footcandles on Work	18	23	32
Relative Visibility*	3.4	2.2	1.8
Condition II			
Source Brightness = 150 footlamberts			
Footcandles on Work	35	48	67
Relative Visibility*	3.6	2.7	1.8
Condition III			
Source Brightness = 390 footlamberts			
Footcandles on Work	110	150	180
Relative Visibility*	3.3	2.2	1.7

*Corrected to a Common Footcandle (10 ft-c) Basis.

TABLE V.—Relative Visibility of Flat Steel Rule (1/64" Divisions) Illuminated by Several Qualities of Lighting

(Ten footcandles on work in all cases)

Method of Lighting	Brightness of Rule (Portion Read) Footlamberts	Relative Visibility
1. Diffusing-type industrial reflector (no reflection of source)	0.8	1.0
2. Diffusing-type industrial reflector (source reflection on portion of rule read) see Fig. 4	25.0	5.5
3. Directional Beam (45 degrees with horizontal)	0.7	1.2
4. Source of Large-Area Low Brightness (Entire rule covered with source reflection) see Fig. 5	25.0	5.5

3.4.4—*Center-punch Marks*

(a) A visual task quite similar to scribing is that of seeing typical center-punch marks. Some relative visibility measurements on punch marks are included in Table VII.

(b) The maximum visibility was experienced when the side of the punch mark opposite the observer reflected the brightness of a light source to the observer's eye.

3.4.5—*Concave Specular Surfaces*

(a) Another difficult seeing task encountered was the inspection of concave specular surfaces for surface defects such as blow holes and irregular scratches. Due to the concavity of these pieces, specular reflections may appear from nearly any sources of light in the surrounding area. Because of this fact, it is believed that the best seeing conditions for detecting the defects would be provided when the concave surface is made uniformly bright. In this case

[5]Studies in Lighting of Intricate Production, Assembly and Inspection Processes, *Transactions I.E.S.*, December, 1937, pages 1026 and 1034.

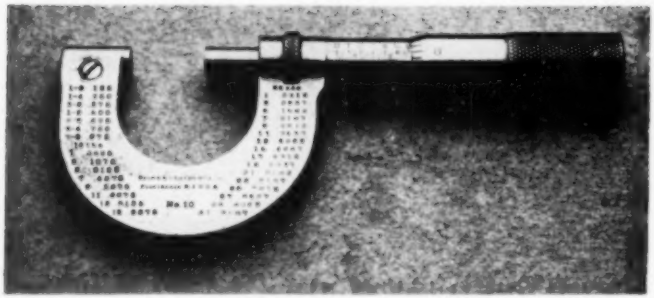


Figure 1. Micrometer caliper properly lighted by a source of large area and low brightness.

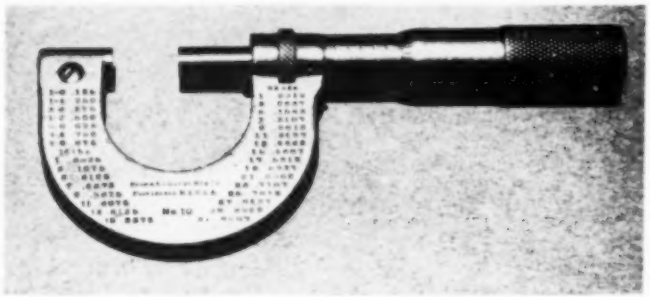


Figure 2. Micrometer caliper poorly lighted by a small light source.

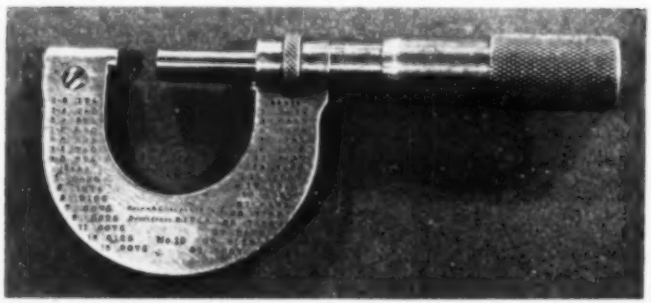


Figure 3. Appearance of micrometer caliper when viewed under a typical general system of industrial reflectors.

the defects appear dark.[4,6] Relative visibility measurements confirmed this belief.

(b) In making these measurements only the viewing angle was changed slightly to obtain either a bright or dark background for the defects. When the surface was bright, the scratches appeared dark, and when it was dark, these defects appeared light. The blowholes appeared dark under all conditions.

[6]Special Lighting Applications for Industrial Processes. *Transactions I.E.S.*, January, 1933, pages 57-81.

4. Design Procedure

4.1—General

(a) Throughout this study, nearly all the experimental work indicated the desirability of a source whose reflected image from the metallic surface would provide a bright background for the detail which must be seen. Accordingly, a design procedure is presented herewith which will indicate the size of the source necessary to produce a reflected image of the required dimensions. This procedure is based upon reflection from specular surfaces. It should be recognized that a non-specular surface will follow this law approximately depending upon the degree of specularity of the surface.

(b) To determine the relation between the size of the source and its reflected image on the working surface the following facts must be established:

(1) The normal position of the operator's eye relative to the work.
(2) The desired coverage of the reflected image of the source (luminous area).
(3) A practical mounting height for the lighting unit.

4.2—Plane Specular Surfaces (Straight Line Cross Section)

Since the angle of reflection is equal to the angle of incidence, the following procedure can be used to establish the size of source necessary to obtain the desired area of reflected brightness. After determining the width of luminous areas necessary, draw lines from the eye to the margins of the proposed luminous area on the work (Fig. 7). At these points erect normals to the surface and construct lines so that the angle of incidence will be equal to the angle of reflection. These lines will form the angle "*S*" which defines the size of the source required for the established mounting height. This angle "*S*" is equal to the angle "*E*" at the eye which is subtended by the luminous area. Fig. 7 represents this condition and applies to any specular surface, the crossection of which is a straight line.

4.3—Convex Specular Surface (Circular Cross Section)

(a) After determining the width of luminous area needed, construct lines from the eye to the margins of the luminous area (Fig. 8). At these points, erect normals to the surface and construct lines from the surface so that the angle of incidence will equal the angle of reflection. The angle "*S*" which these lines make when projected below the cylindrical surface can be shown to equal twice the angle "*C*" at the center of the cylinder subtended by the reflection of the source, plus the angle "*E*" at the eye which is subtended by the reflection of the source (See Appendix). Angle "*S*" defines the size of the source required

for the established mounting height.

(b) A simple chart based upon this formula will be found in Fig. 9 which indicates the size of source (in degrees of the subtended angle "*S*") necessary to produce any width of band upon various size cylinders. This is applicable to any specular object with a circular cross section in the plane of that section. The position of the source can be determined by drawing the line from the eye to one edge of the luminous area or band. At this point, construct a normal to the surface and draw a line so that the angle of incidence equals the angle of reflection. One edge of the source will then be on this line at the desired mounting height.

(c) It can be shown that the same general procedure can be applied to concave surfaces (See Appendix.)

5. Conclusions and Recommendations

5.1—Summary

(a) The experimental work indicates a desirability of diffusing light sources of comparatively low brightness which subtend a large angle at the point of work. This condition can be met by a source of small physical size close to the work or by a large source subtending the same angle at a greater distance from the work.

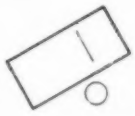
(b) The general lighting should, insofar as is practical, meet this specification. Indirect lighting of the ceiling is a common way of providing a large area diffusing source. An approximation of such a source may be obtained from a general lighting system employing fluorescent lamp luminaires arranged in grid patterns.

(c) In cases where physical conditions render impractical the use of the ceiling as a secondary light source, or where the desired results cannot be obtained advantageously with fluores-

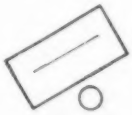
TABLE VI.—Relative Visibilities of Scribed Marks Under Equal Illumination (10 footcandles)

Type of Source	Position of Scribed Marks*	Types of Lighting		
		Directional from Left, 45 degrees with Horizontal	System of Diffusing Type Industrial Reflectors	Large-Area Low Brightness Source
1. Untreated steel (cold rolled)	A	7.9		
	B	1.7		
	C	1.6	1.3	5.8
	D	1.6	at threshold	6.8
2. Steel treated with copper sulfate	A-1	9.3		
	B-1	3.4		
	C-1	1.8	1.2	4.7
	D-1	1.8	1.2	7.1
	A-2	13.6		
	B-2	1.5		
	C-2	2.0	2.0	3.9
	D-2	1.8	at threshold	6.2
3. Steel treated with commercial dye	A	7.8		
	B	1.5		
	C	1.7	1.9	8.1
	D	1.7	2.3	10.9
4. Diffuse aluminum	A	8.9		
	B	1.6		
	C	2.7	1.1	Greater than 20
	D	2.3	1.8	Greater than 20
5. Specular aluminum	A	9.0		
	B	2.6		
	C	3.0	2.9	Greater than 20
	D	2.9	3.4	Greater than 20

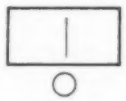
*Position of Scribed Marks (|) with respect to the observer ○ are indicated in the following sketches:



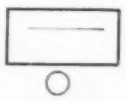
A — Piece oriented for maximum visibility of scribing when viewed under the directional light.
A-1 — Copper Sulfate treated piece oriented for maximum visibility of the scribing which is parallel to the marks of the emery (used to clean the surface before application of the copper sulfate).
A-2 — Copper Sulfate treated piece oriented for maximum visibility of the scribing which is normal to the emery marks.



B — Scribing at right angles to that of maximum visibility
B-1 — Scribing at right angles to that described in A-1
B-2 — Scribing at right angles to that described in A-2



C — Scribing parallel to the line of vision
C-1 — Copper Sulfate treated piece positioned so that scribing parallel to emery marks is parallel to line of vision
C-2 — Copper Sulfate treated piece so that scribing normal to emery marks is parallel to line of vision



D — Scribing normal to the line of vision
D-1 — Scribing at right angles to that described in C-1
D-2 — Scribing at right angles to that described in C-2

Figure 4. Appearance of steel rule under a typical general system of industrial reflectors.

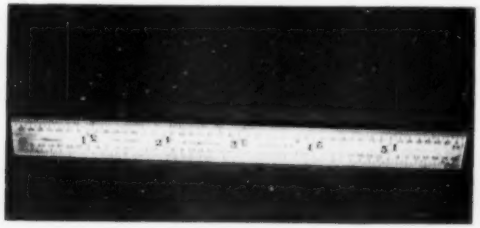


Figure 5. Appearance of steel rule under a source of large area and low brightness.

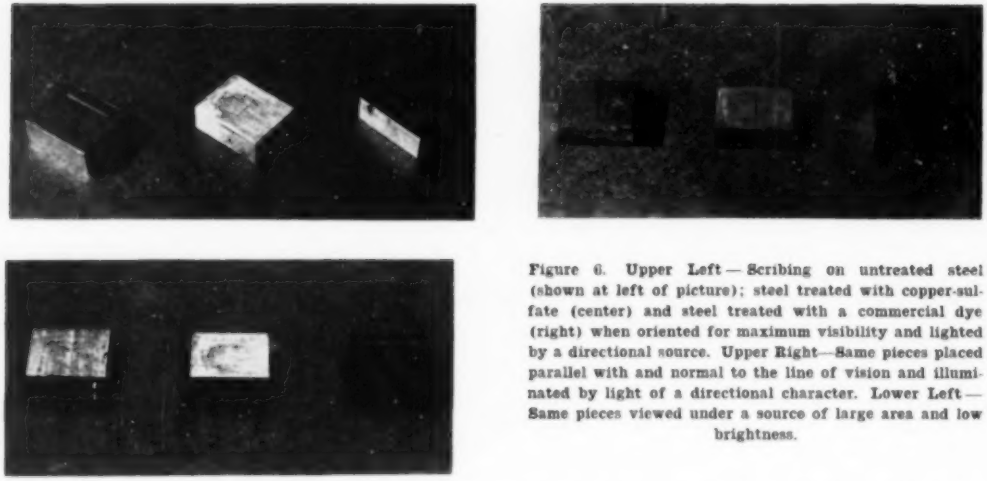


Figure 6. Upper Left — Scribing on untreated steel (shown at left of picture); steel treated with copper-sulfate (center) and steel treated with a commercial dye (right) when oriented for maximum visibility and lighted by a directional source. Upper Right—Same pieces placed parallel with and normal to the line of vision and illuminated by light of a directional character. Lower Left — Same pieces viewed under a source of large area and low brightness.

cent lamp grid systems, the lighting specification should be fulfilled by smaller sources, mounted relatively close to the work. In addition, general lighting in accordance with present accepted practice should be provided. Extraneous glare sources and high brightness ratios should be minimized in order to provide the best seeing conditions. This is particularly true where the work surfaces are of specular metal.

(d) Light-colored ceilings and upper walls materially improve visibility due to the decrease in brightness ratio.

(e) No specific spectral quality of light is recommended for maximum visibility.

5.2—General Lighting

(a) This report establishes the desirability of light sources which are large in area, and of uniform brightness. Until recently, it has been difficult to obtain this type of illumination due to the fact that the available sources were small in size and of high intrinsic brightness. This meant that equipment had to be designed to give a high order of diffusion.

(b) The fluorescent lamp has made it easy to obtain a good approximation of a large area uniform brightness light source. It should be remembered, however, that the typical fluorescent unit consisting of one or more lamps in a trough reflector, is in reality an extended linear source rather than a true large area source. Where actual large area sources are necessary, they can be readily constructed by the use of several fluorescent lamps behind a diffusing panel. In many cases, however, the linear characteristics of the fluorescent unit can be utilized to advantage without the complication of grouping the lamps in a bank. In the case of the micrometer barrel, for example, or the cylindrical feeds on machine tools, it is possible to secure satisfactory reflected images when a row of fluorescent units is mounted with its length at right angles to a line parallel to the axis of the cylindrical scale. By orienting the fixtures in this manner, the image reflected on the cylindrical scale extends around the scale a sufficient distance so that the graduations are easily read. If the row is mounted with its length parallel to the axis of the cylindrical scale, only a narrow band of light is reflected, making it rather difficult to read the graduation. Most machines have dials and scales mounted at various angles with respect to the machine, and in order to make the dials easily readable regardless of the position of the machines in the room, the best solution appears to be to use fluorescent units in what is known as a grid pattern. It will be noted from Fig. 10 that this system consists of continuous rows of fluorescent lamps plus essentially continuous rows mounted at right angles to the first group. The grid system provides a fair approximation of the seeing conditions that would be obtained under a panel of uniform brightness covering the ceiling. This condition can be further improved by using fluorescent lamps of lower than normal brightness, reflectors with louvers, or diffusing covers or by making the ceiling brighter.

5.3—Supplementary Lighting

(a) It is sometimes necessary to perform critical visual tasks in shadows cast by overhead projections of the machine or work or by the operator.

TABLE VII.—Relative Visibilities of Center-Punch Marks Under Equal Illumination (10 Footcandles)

Metal	Directional from Left—45 degrees with Horizontal	Directional Source Between Observer and Task — 45 degrees with Horizontal	Source of Large Area and Low Brightness
Untreated Steel (Cold Rolled)	1.5	2.6	1.7
Brass	1.7	8.9	5.3

TABLE VIII.—Relative Visibility of Defects on Concave Specular Surface (Source Brightness Constant—220 Footlamberts)

Defect	Relative Visibility — Background of Defect	
	Bright	Dark
1. Horizontal Scratch	4.3	4.3
2. Vertical Parallel Scratches	6.1	2.7
3. Blowhole	Greater than 20	1.8

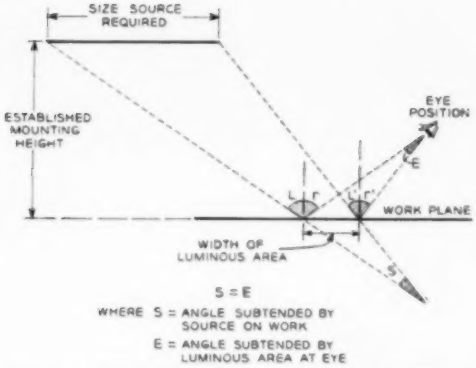

SIZE SOURCE REQUIRED
ESTABLISHED MOUNTING HEIGHT
EYE POSITION
E
WORK PLANE
WIDTH OF LUMINOUS AREA
S = E
WHERE S = ANGLE SUBTENDED BY SOURCE ON WORK
E = ANGLE SUBTENDED BY LUMINOUS AREA AT EYE

Figure 7. Showing procedure to be used in establishing the size of source necessary to obtain the desired area of reflected brightness when applied to a plain specular surface.

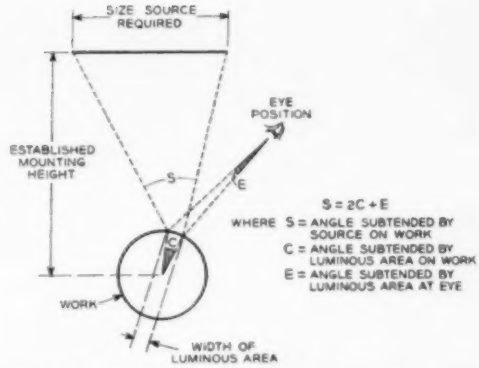

SIZE SOURCE REQUIRED
EYE POSITION
ESTABLISHED MOUNTING HEIGHT
S
E
S = 2C + E
WHERE S = ANGLE SUBTENDED BY SOURCE ON WORK
C = ANGLE SUBTENDED BY LUMINOUS AREA ON WORK
E = ANGLE SUBTENDED BY LUMINOUS AREA AT EYE
C
WORK
WIDTH OF LUMINOUS AREA

Figure 8. Showing procedure to be used in establishing the size of source necessary to obtain the desired area of reflected brightness when applied to a convex specular surface.

Many work areas are located on other than horizontal surfaces. It is often difficult to light these areas properly from a general lighting system and, therefore, supplementary lighting of the proper direction, quantity and quality for the particular task involved is required.

(b) For supplementary lighting applications, both filament and fluorescent units are widely used. Units using fluorescent lamps provide greater diffusion, less shadows and lower reflected brightnesses. The filament lamp, on the other hand, is basically a high brightness concentrated source; therefore, it is relatively easy to control the illumination in whatever type of beam pattern is desired. This means that when it is desirable to produce a highly directional type of illumination, a filament unit is the logical choice. Filament units, in general, are small which is an advantage where space is a critical factor.

(c) In certain cases the color of light has an important bearing on the ease of seeing of a particular task. In such cases, the fluorescent unit is the usual choice, due to the high efficiency production of colored light (daylight, blue, green, etc.).

5.4—Maintenance

The maintenance of lighting equipment is a serious problem which often is neglected. When we realize that a lighting system can lose over 50 per cent of its illumination in a short time due to poor maintenance, it is obvious that this problem should receive careful consideration. In fact, no modern lighting system can be considered well planned unless a good maintenance program is an integral part of it.

5.5—Lighting for Specific Tasks

5.5.1—*Portable Measuring Instruments*

5.5.1.1—*Flat Steel Rules*

(a) The seeing task is the observation of cut numbers and divisions on a semi-polished metal surface. This surface functions as a plane mirror. It was found that the best visibility was obtained when the background was bright by reason of its specular reflection of a luminous surface. The size and brightness of this source, as well as its position relative to the operator, materially affect the visibility of the rule.

(b) The source (or sources) of illumination should be of sufficient size and so located that its image (or their images) will be reflected by the entire section of the rule in which the operator is interested. The design procedure (page 618) should be applied to obtain the source dimensions which will fulfill this condition. The source should be of a nearly uniform brightness of between 150 and 250 footlamberts.

5.5.1.2—*Micrometer Calipers*

(a) The micrometer barrel is usually a polished surface and the cut

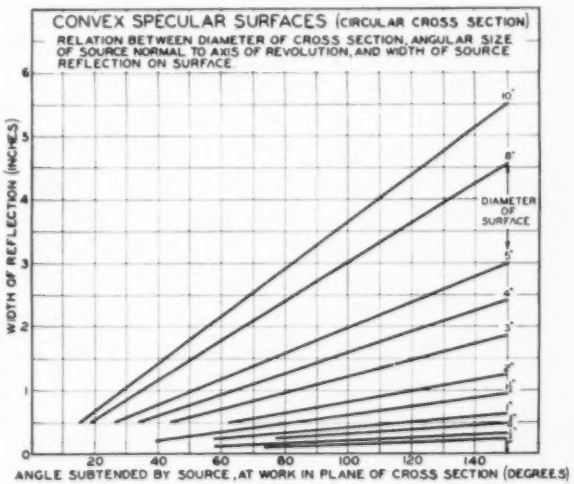


Figure 9.

Figure 10. Fluorescent lighting units arranged in a grid pattern.

numbers and divisions appear as dark lines. The seeing task is therefore the observation of dark lines against a semi-polished metallic background. This polished surface background (micrometer barrel), however, functions as a convex mirror and redirects light into the operator's eyes regardless of the position of the light source.

(b) It was found, however, that the relative position of a light source to the operator materially affects the visibility of the seeing task. So, too, do the size and brightness of that source. Furthermore, it was observed that the operator would move the micrometer to a shaded area and utilize a reduced quantity of light in order to take advantage of the improved quality of lighting.

(c) The source (or sources) of illumination should be of sufficient size and so located that its reflected image (or their images) will cover a sector at least 50° wide around the periphery of the micrometer barrel. The design procedure (page 618) for the illumination of convex specular surfaces should be applied in the plane normal to the axis of the barrel. The source dimensions at right angles to this plane are not significant as the reflection of even a point source covers the entire length of the micrometer barrel. Any additional width will provide a factor of safety for other positions of the micrometer caliper. In cases where it will be used in various positions provision for adequate source size should be made.

(d) The source should be of a nearly uniform brightness of between 150 and 250 footlamberts. The lower brightness value is preferable except in locations where the reflection of other luminaires, windows, or sources of brightness will be superimposed on the 50° sector of the micrometer barrel. Under such conditions the higher value is desirable since it tends to minimize the reflected interference of the extraneous light sources.

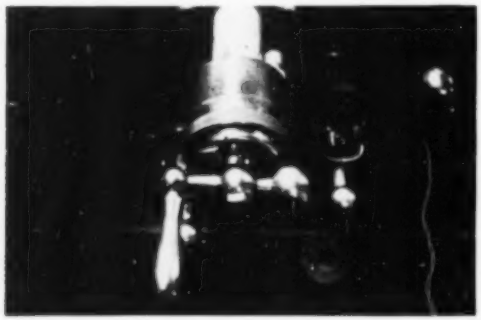
5.5.2—*Bench Work*

(a) Bench work is extremely varied in character. In the main, however, the tasks may be considered as layout work and hand finishing. Hammers, chisels, files, rules, micrometer calipers, prick punches, scribes, etc., are the usual tools.

(b) Probably the most difficult visual tasks are scribing and the reading of rules and micrometer calipers. If the lighting is adequate for these, it will in most instances suffice for the remaining tasks.

(c) Scribing is the marking by scratching of guide or limit lines on the surface of a piece of material before machining. Size, weight, shape, and material composition of the work piece are obviously variable factors.

(d) Upon an untreated and clean surface, the line may be nearly invisible if not properly oriented with respect to the source unless lighted by large area low brightness source. The relative position of the work piece, workman and light source are quite critical and no fixed concentrating source affords universal satisfaction. In such cases (untreated and clean surfaces) the scribed lines appear most visible when a concentrating source is directed so that no specular reflection from the surfaces is reflected to the eyes, but the reflection from the side of the scribed line appears bright against the dark surface background.



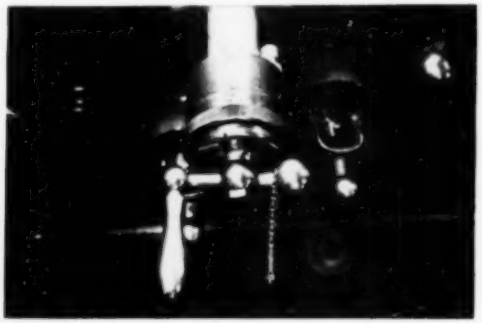


Figure 11a. (Left) — Cross-feed micrometer collar of a lathe lighted by a general system of industrial reflectors.
11b. (Right) — Cross-feed micrometer collar of a lathe lighted by a source of large area and low brightness.

(e) The objection to such a system of lighting is that only those scribed marks which are properly oriented with reference to the light source have good visibility. Also, the best position of the piece for viewing varies with different positions of the eye. With the eye immediately above the work, as is apt to be the case when actually scribing, the lines are best oriented when perpendicular to the light rays. When viewing the work from the side of a bench, the piece must be rotated to gain the best visibility; the exact angle of rotation depending upon the position of the light source, the height of the observer and the height of the work.

(f) If the piece is first cleaned with emery and then treated with copper sulfate, a layer of copper is deposited upon the surface. When the scribing is done, copper is removed, exposing the metal which appears bright in contrast to the copper background. With directional lighting, the lines perpendicular to the emery marks are fairly visible, but lines parallel to the emery marks may be nearly invisible unless oriented to a vantage point for maximum visibility.

(g) There are available fluids for coating metal which are dark in appearance and dry quickly. The scriber cuts through this coloring and the metal shows as bright lines. With such a covering applied to the work, visibility is improved. The best visibility for scribed lines in all directions is obtained when illuminated by a source of large area and low brightness.

(h) It should be noted that steel may have a rather low reflection factor due to a coating of oxide, dirt, oil, etc. When such a piece is scribed, it is similar in appearance to steel which has been purposely treated with a fluid of low reflectance.

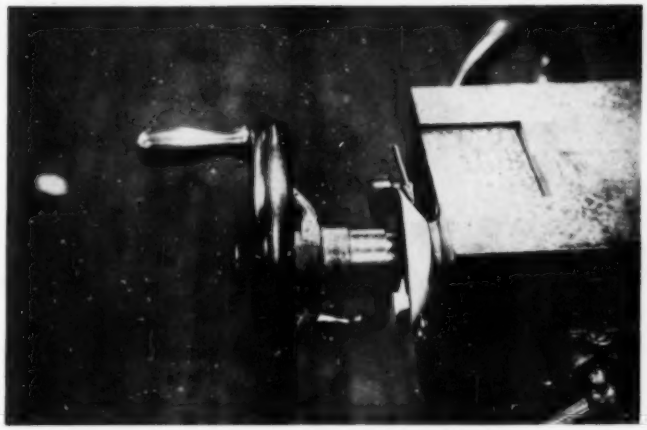


Figure 12. Application of reflecting collar to graduated feed indicating dial.

5.5.3—*Machine Tools*

5.5.3.1—*Graduated Feed Indicating Scales*

(a) The seeing task is the observation of cut numbers and divisions on a semi-polished metal surface. This surface acts as a cylindrical convex mirror which redirects light into the operator's eye from light sources in many positions. It was found that the best visibility was obtained when the background was uniformly bright by reason of its specular reflection of a luminous surface (Fig. 11-B).

(b) Micrometer collars are ordinarily made with 100 divisions, indexed by ten's. The band of reflected light should cover a sector of at least 36° in order to include one set of divisions and one numerical index.

(c) Circular scales are usually indexed every 10° and hence an illuminated band of only 10° would be necessary.

(d) The source position should be selected so its reflected image will be centered about the stationary index of the collar. The design procedure for convex surfaces can be applied to ascertain the source size necessary to produce the desired bands of illumination.

(e) In some cases improved visibility of vertical or inclined graduated machine scales can be obtained by installing a small reflecting surface ad-

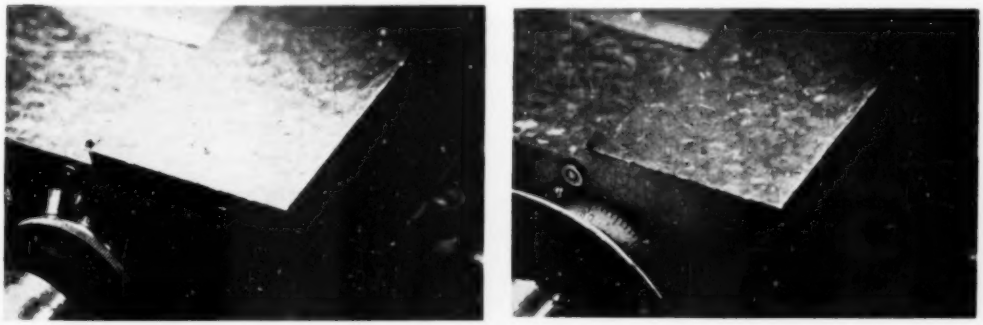


Figure 13. Appearance of graduated feed indicating scale. A. (Left) — Under typical general lighting system. B. (Right) — With reflecting collar.

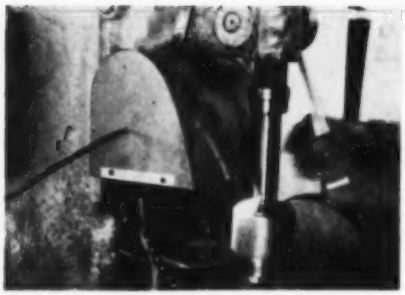


Figure 14. Experimental unit installed upon a drill press presents a relatively large source.

Figure 15. Appearance of work when lighted by experimental drill-press unit.

jacent to the scale and at a 45° angle with the horizontal (Fig. 12). The reflection of this surface in the scale provides a lighter background for the numerals and divisions (Figs. 13-A and 13-B). A matte surface of high reflectivity, which is durable and easily maintained, is most satisfactory.

Precision Type Lathes

(a) The most severe visual tasks encountered on the lathe involve the reading of the following vernier scales:

1. Cross feed micrometer collar with 100 divisions numbered by 10's.
2. Compound rest graduated micrometer collar (divided as #1).
3. Compound rest swivel graduated in 180°, numbered every 10°. These scales are marked on horizontal or vertical surfaces depending upon the manufacture.
4. Tailstock spindle (not graduated on all lathes).
5. Micrometer carriage stop (divided as #1).
6. Taper attachment—(located at the rear of the lathe bed) graduated in degrees on one end and inches per foot on the other end.
7. Milling and keyway attachment—vertical feed with graduated micrometer collar. Vertical and horizontal swivels, both graduated in degrees.

(b) Precision lathe operation is dependent upon the accuracy of the setting up and the use of the graduated feed indicating dials rather than observation of the cutting tool in its path. The work is checked by portable measuring instruments. The use of these instruments on the work, plus the occasional need of seeing a reference point on the work, render imperative good seeing conditions in the immediate working area of the lathe in addition to the illumination of the feed indicating dials.

(c) Lighting recommendations for graduated feed indicating dials apply to the scales enumerated above. It is appreciated that the many verniers and their locations complicate the lighting problem. It is suggested, however, that a practical compromise be made which satisfactorily meets the requirements.

(d) In some cases, it may be desirable to provide a supplementary directional source for boring operations.

5.5.3.3—*Internal Grinder*

(a) The visual task of setting up work on the internal grinder is not particularly severe. The work is centered approximately and fastened to the chuck which is then placed on the machine. The final centering of the work is done with the aid of indicating dials.

(b) When the internal grinder is in operation a hood is drawn completely over the work. However, the hood which is hinged at the rear is raised during the setting-up operation. In the raised position it still intercepts a considerable quantity of light, although by painting the inside surface of the hood white, or by placing an insert of high reflectivity and durable surface therein, the lighting on the indicator can be materially increased.

(c) The start of the cut is indicated by the spark shower and again is not a difficult seeing task. Depending upon the type of work, internal micrometers, gauges, verniers, or other such types of measuring instruments are used.

(d) The seeing task of reading the cross-feed verniers is that of reading a graduated feed scale and these lighting recommendations will apply.

(e) The machine on which these observations were made was painted a light buff. Reflection from a horizontal section of the machine was helpful in seeing the graduations on the head stock. It is recommended that such sections be finished a light color to facilitate scale readings wherever possible.

5.5.3.4—*External Grinder*

(a) Setting up work is not a severe seeing task. The work is approximately centered by eye and the final centering is done with the aid of indicating dials.

(b) The start of the cut is indicated by the spark shower which is not a difficult visual task. Depending upon the type of work, gauges, micrometer calipers, verniers, or other such types of measuring instruments are used.

(c) The seeing task of reading the cross-feed vernier is that of reading a graduated feed scale and these lighting recommendations will apply. The reading of micrometer calipers and other measuring devices are, however, the most critical seeing tasks and the lighting should be adequate for these.

5.5.3.5—*Surface Grinder*—The seeing tasks for the surface grinder are similar to those of the internal and external grinders with the simplification that all work is on a plane surface. Setting up is not difficult and the few graduated micrometer collars require the illumination described under that heading.

5.5.3.6—*Universal and Vertical Millers*

(a) The visual task of setting up work usually is not severe. Seeing tasks are the observation of graduated feed-indicating collars for the control of the various movements, as well as frequently milling to a guide line scribed on the work surface.

(b) The latter visual task is one of the most difficult ones encountered in

the tool room, and requires special treatment for an adequate solution. The visual requirements are similar to those of scribing plus the presence of the milling tool. This will cast a shadow upon the most critical sections of the work area unless a source subtending a large angle is used. The usual type of high mounted source of large area and low brightness may not be completely satisfactory because the milling head as well as the tools tend to shadow the working area. A diffusing source subtending a large angle mounted close to the working area achieves the best results. Lighting recommendations for graduated feed-indicating dials should be applied for such dials.

5.5.3.7—*Shapers*—The principal visual tasks involve the reading of graduated feed-indicating scales and portable measuring instruments. In general, a slight amount of stock is left on the work for the final operations, so that measurements are not as critical as in finishing operations. However, good visibility is required and the recommendations which apply for the lighting of gradnated feed-indicating scales should be followed.

5.5.3.8—*Drill Press*—The visual task is that of centering the drill to a punch mark on the work. Although maximum visibility was obtained with a source on the same side of the work as the eye, this position is difficult to attain practically. Consequently, it is recommended that a source of low-brightness specularly reflected by the work surface (Fig. 14) be employed.

5.5.4—*Inspection of Polished Surfaces*

5.5.4.1—*Introductory Explanation*—One of the severest problems encountered in the course of this study was the inspection of mirror-like (highly specular) concave semi-cylindrical bearing surfaces. These bearings are inspected for such defects as blow holes, deep scratches, pits, dings, machine scratches, irregular scratches, and chatter marks. Unfortunately, no single quality of lighting was found to provide the best seeing conditions for the recognition of all of these various defects. The defects have been grouped according to the types of lighting which provide good seeing conditions.

5.5.4.2—*Blow Holes, Deep Scratches, Dings and Pits*—These defects are usually dark in appearance and are most readily visible when seen by contrast against a light background. The specular metallic background should be uniformly bright by reason of the specular reflection of a luminous source of relatively low brightness. In accordance with present knowledge, care must be taken that the brightness ratios in the field of vision are not greater than 10 to 1. If a high brightness of the polished metal surface is needed for the recognition of defects, it may be necessary to lighten the surroundings of the work (such as the top of the work bench) so that the brightness ratios fall within the above limits. The size and position of the light source depend almost entirely upon the dimensions and contour of the piece which is being inspected.

5.5.4.3—*Machine and Irregular Scratches*—The nearly negligible depth of this type of scratch allows diffuse light to brighten the sides and bottom of the scratches so that there is poor contrast between the scratch and its metallic background if it also is reflecting the source of the diffused light to the eye. These defects can best be seen by their specular reflection of a directional or semi-directional light source to the eye when the metallic background appears dark. Thus, it is important that the surface be so placed relative to the light source that only the sides of the scratches will reflect the directional light into the eye, and the polished surface directs its reflection away from the eye. It is helpful if uniform neutral color is reflected to the eye. Such a reflection eliminates confusing color images and affords a more ready recognition of the scratch defect. The placement of such a light source and background is dependent upon the specific task and the physical arrangement of the work area.

5.5.4.4—*Chatter Marks*

(a) Chatter causes a series of ripples on the polished surface. The depth of these ripples frequently is too slight to be measured by usual methods. In this case they can best be identified by the distorted image of lines on a luminous source which is specularly reflected by the polished surface on which the chatter occurs.[6]

[6]Special Lighting Applications for Industrial Processes, *Transactions I.E.S.*, January, 1933, pages 57-81.

(b) A satisfactory light source for the inspection of chatter marks is a low-brightness, luminous panel upon which several parallel black lines are superimposed. Good visibility is also obtained with a matte white surface panel upon which parallel black lines are drawn, if the panel is uniformly lighted from a source shielded from the eyes of the operator.

Appendix

The geometrical proof of the relation between the source size (also expressed as the angle subtended by the source at the point of work) and the size (and position in case of plane reflection) of its reflected image from plane, convex and concave surfaces of circular crossection is presented.

Plane Specular Surface
(Straight Line Cross Section)

The image of a point source of light (B) will appear on a plane specular surface at a point (D) which divides the distance ($B'F$) between the perpendicular from the source and the perpendicular from the eye to the plane, proportional to the ratio between the height of the source (BB') and the height of the eye (EF) above the plane. The shorter distance is adjacent to the lesser height.

$\triangle ACA'$ & EFC are similar $\quad \angle a = \angle d$

$\triangle BDB'$ & EFD are similar $\quad \angle e = \angle h$

Source height $AA' = BB' = h_s$

Eye height $EF = h_e$

$$B'D : DF :: BB' : EF$$

The ratio between the width (CD) of the image of a light source in a plane specular surface and the width of the source proper (AB) is equal to the ratio between the height of the eye (EF) above the plane and the sum of the heights of the eye (EF) and the source (BB') above the plane. (Refer to Fig. A and Equation A.)

Convex Specular Surface
(Circular Cross Section)

The angle S at the work subtended by a source of brightness, is equal to twice the angle C at the center of curvature subtended by the reflection of the source, plus the angle E at the eye subtended by the reflection of the source. (See Fig. B, Cases I and II.)

Concave Specular Surface
(Circular Cross Section)

The angle S at the work* subtended by a source of brightness, is equal to twice the angle C at the center of curvature subtended by the reflection of the source, minus the angle E at the eye subtended by the reflection of the source. (See Fig. C, Cases I and II).

*The vertex of the angle S varies in position depending upon the relative positions of the source, the work, and the eye. For practical design considerations the vertex may be assumed at the center of the curvature of the surface.

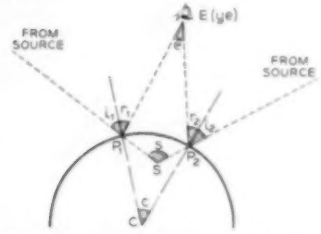


Figure B—Case I. Convex specular surface; eye within source angle.

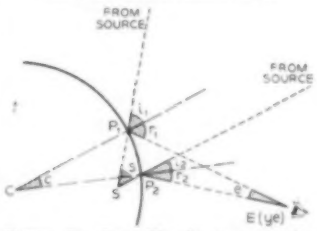


Figure B.—Case II. Convex specular surface; eye outside source angle.

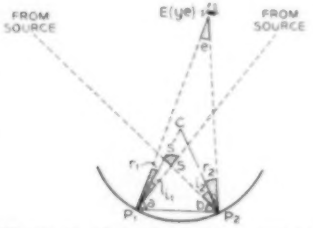


Figure C.—Case I. Concave specular surface; eye within source angle.

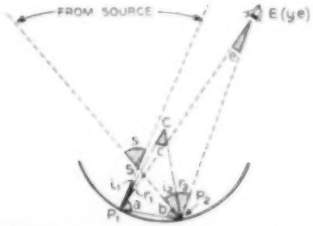


Figure C.—Case II. Concave specular surface; eye outside source angle.

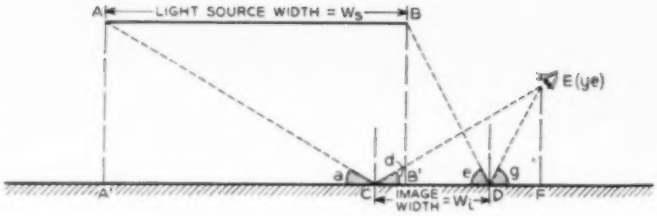


Figure A. Plane Specular surface.

$$(A) \qquad h_i : h_s :: DF : B'D :: CF : A'C$$
$$h_i : h_s + h_e :: CF : A'C + CF :: DF : B'D + DF$$
$$B'D + DF : A'C + CF :: DF : CF$$
$$B'D + DF : A'C + CF - (B'D + DF) :: DF : CF - DF$$
$$CF - DF : A'C + CF - (B'D + DF) :: DF : B'D + DF :: h_e : h_s + h_e$$
$$CF - DF = W_i = Image\ Width$$
$$A'C + CF - (B'D + DF) = W_e = Source\ Width$$
$$W_i : W_e :: h_e : h_s + h_e$$

Proof: Case I

Polygon EP_2CP_1: $\quad \angle e + \angle EP_2C + \angle e + \angle CP_1E = 360°$

$\angle EP_2C = 180° - \angle r_2 \qquad \angle CP_1E = 180° - \angle r_1$

$\angle e + 180° - \angle r_2 + \angle e + 180° - \angle r_1 = 360°$

$\angle e + \angle e = \angle r_1 + \angle r_2$ *or* $2\angle e + 2\angle e = 2\angle r_1 + 2\angle r_2$

Polygon EP_2SP_1: $\quad \angle e + \angle EP_2S + \angle s + \angle SP_1E = 360°$

$\angle EP_2S = 180° - 2\angle r_2 \qquad \angle SP_1E = 180° - 2\angle r_1 \qquad (\angle r_1 = \angle i_1)$

$\angle e + 180° - 2\angle r_2 + \angle s + 180° - 2\angle r_1 = 360°$

$\angle e + \angle s = 2\angle r_2 + 2\angle r_1 = 2\angle e + 2\angle e$

$\angle s = 2\angle e + \angle e$

Proof: Case II

Polygon EP_2CP_1: $\quad \angle e + \angle EP_2C + \angle e + \angle CP_1E = 360°$

$\angle EP_2C = 180° + \angle r_2 \qquad \angle CP_1E = 180° - \angle r_1$

$\angle e + 180° + \angle r_2 - \angle e + 180° + \angle r_1 = 360°$

$\angle r_1 = \angle e + \angle r_2 + \angle e$

Polygon EP_2SP_1: $\quad \angle e + \angle EP_2S + \angle s + \angle SP_1E = 360°$

$\angle EP_2S = 180° + 2\angle r_2 \qquad \angle SP_1E = 180° - 2\angle r_1 \qquad (\angle r_1 = \angle i_1)$

$\angle e + 180° + 2\angle r_2 + \angle s + 180° - 2\angle r_1 = 360°$

$\angle s = 2\angle r_1 - 2\angle r_2 - \angle e = 2\angle e + 2\angle r_2 + 2\angle e - 2\angle r_2 - \angle e$

$\angle s = 2\angle e + \angle e$

Proof: Case I

$\triangle SP_1P_2$	$180° = \angle s + \angle a + \angle b$	(1)
$\triangle CP_1P_2$	$180° = \angle e + \angle a + \angle i_1 + \angle b + \angle i_2$	(2)
$\triangle EP_1P_2$	$180° = \angle e + \angle a + \angle i_1 + \angle r_1 + \angle b + \angle i_2 + \angle r_2$	(3)
Double (2)	$360° = 2\angle e + 2\angle a + 2\angle i_1 + 2\angle b + 2\angle i_2$	(4)
Add (1 + 3)	$360° = \angle s + \angle e + 2\angle a + 2\angle i_1 + 2\angle b + 2\angle i_2$	(5)
Subt (4 − 5)	$0° = 2\angle e - \angle s - \angle e \qquad (\angle i_1 = \angle r_1)$	
	$\angle s = 2\angle e - \angle e$	

Proof: Case II

$\triangle SP_1P_2$	$180° = \angle s + \angle a + \angle i_1 + \angle r_1 + \angle b$	(1)
$\triangle CP_1P_2$	$180° = \angle e + \angle a + \angle r_1 + \angle b + \angle i_2$	(2)
$\triangle EP_1P_2$	$180° = \angle e + \angle a + \angle b + \angle i_2 + \angle r_2$	(3)
Double (2)	$360° = 2\angle e + 2\angle a + 2\angle r_1 + 2\angle b + 2\angle r_2$	(4)
Add (1 + 3)	$360° = \angle s + \angle e + 2\angle a + 2\angle r_1 + 2\angle b + 2\angle r_2$	(5)
Subt (4 − 5)	$0° = 2\angle e - \angle s - \angle e \qquad (\angle i_1 = \angle r_1)$	
	$\angle s = 2\angle e - \angle e$	

T E L E C A S T

LIGHTING NEWS OF CURRENT INTEREST

I.C.I. Seeks International Standard for Automotive Headlights

A study meeting recently was held in Paris under the auspices of the International Commission on Illumination for the purpose of studying the problem of an international standard for automotive headlights. The suggestion that an appropriate international standard should be developed originated with the United Nations, and initially was directed to the International Electro-technical Commission which in turn referred the matter to the I.C.I. as the appropriate agency for the development of such a technical standard.

With such a great divergence as exists among the various nations as to specifications governing automotive headlights, and with the rapidly increasing number of U. S. automobiles operating on either a transient or permanent basis in the different countries of the world, the question of an appropriate international standard has rapidly assumed increasing importance. The recent Paris meeting concerned itself primarily with such necessary initial steps as the development and establishment of a procedure for comparative testing to provide a suitable basis for the establishment of standard specifications for beam pattern and other technical points. Another parallel problem is the development of a program and procedure looking to the introduction and general adoption of an international standard.

Psychological Reactions Cause Chemical Results

What was thought to be poisonous gas in a Texas office turned out to be an individual psychological - chemical reaction resulting from maladjusted lighting, according to an item published in the August 1949 issue of *Industrial Hygiene Letter* (published by the Federal Security Agency, Washington, D. C.), from which the following is excerpted.

An example of an unusual request received by the Texas State Department of Health, Industrial Hygiene Section, developed in Austin when two women complained that they believed poisonous gases were emanating from the basement of their office building. Upon investigation of the premises, the basement proved to be free of carbon monoxide and hydrogen sulfide, yet the women insisted that they experienced a sweet taste in their mouths after a short time in the room, and that this sweet taste later turned to a brassy, metallic taste.

Study of their working room disclosed that it was illuminated by 4-foot industrial type fluorescent luminaires at a distance of about 8 feet from the floor and that their desks were placed before a large mirror. The two women submitted to dental examination which revealed bimetallic fillings in their teeth, and, with that clue, a theoretical explanation was reached.

The fluorescent lights hanging too closely to their desks produced such a ghastly appearance on their mirrored faces that it was concluded that their reaction produced a purely psychological trouble. Their fear and worry over their ghastly appearance resulted in a reduced pH of the Saliva. This in turn accounted for the brassy, metallic taste they experienced, since this taste is common where bimetallic fillings are present and there is a low pH of saliva.

When the situation was explained to the two women they agreed to use an incandescent desk lamp until the fluorescent luminaires could be raised to at least a 10-foot level, and different tubes providing more red color could be installed. When this had been done, the symptoms disappeared entirely.

Transmitting Messages by Infrared Light

Message transmission by radio wireless is very difficult to keep secret. Using the visible blinker system may be more limited but may also be slow and uncertain in bad weather. Recently the caesium vapor lamp has been perfected so that its output of invisible infrared radiation can be modulated and can be picked up by a photocell received at the designated target, hence permitting voice communication over a beam of radiation that penetrates all sorts of weather and which cannot be picked up by enemy listeners. The caesium vapor lamp looks very much like the familiar sodium vapor lamp except that its output is of too long a wave-length to excite human vision.

National Association of Electrical Distributors New Name for NEWA

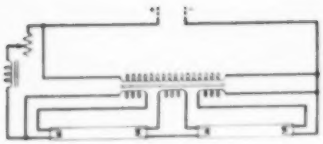
Effective September 1, 1949, the Board of Governors of the organization known for many years as the National Electrical Wholesalers Association announced that the association's name had been changed to National Association of Electrical Distributors.

It was the opinion of the Board that the indispensable economic functions of the modern distributor of electrical apparatus, supplies and appliances are more appropriately reflected by the more modern designation — National Association of Electrical Distributors. The Association's offices are located at 500 Fifth Ave., New York 18, N. Y.

Dimmer Circuit for Fluorescent Stage Lighting

A demonstration of dimmer-controlled stage lighting by fluorescent lamps was given in June at the Bolton's Theatre, according to a report published in the current July issue of "Light and Lighting," the official journal of the British Illuminating Engineering Society. From this report the following excerpts are presented.

Lamps giving green, blue and red light produced good color effects. The green and blue were obtained by the use of appropriate phosphors in the



Fluorescent dimming circuit.

tubes; the red was obtained by the use of filters. Luminaires utilizing 2-foot 40-watt tubes were used for floodlights, wing floods and top battens. The different colored lamps were in positions parallel to each other, giving the effect of an almost unbroken line along the footlights and battens.

The installation gave a uniform illumination over the stage, and also put considerable light on the draperies. However, it is possible that fluorescent lighting might be considered to give a rather flat effect compared with filament lighting which gives a better effect of light and shade—a point which might be of some importance in the lighting of a straight play as opposed to some more spectacular show.

The range of dimming required for stage purposes is at least 300 to 1. The circuit used for fluorescent dimming (see accompanying diagram) is a development of a quick-starting circuit. In the normal arrangement of this circuit, the filaments are heated by a transformer whose primary is connected across the lamp. When power is switched into this circuit, practically full line voltage is applied across this transformer, and the filaments are heated rapidly. When the lamp strikes (in less than a half second) the voltage across the transformer is reduced about half, and the heating current falls to a low value.

In the circuit as modified for dimming purposes, the filament transformer is connected directly across the supply line. This increases the range of dimming to a marked degree, and the light output can be reduced on a 5-foot 80-watt lamp to about 4 per cent of normal. The range of dimming required for theatre use, however, is obtained only by using lamps in which the ratio of diameter to length is much higher; the best current lamp is the 2-foot 40-watt lamp. By using two of these in combination with a filament transformer having an extra secondary winding for the center pair of filaments, the range of dimming is increased to give a minimum value of approximately 2.3 per cent. A good ground connection in close proximity to the lamps is required for effective operation. To get not only good dimming but also an effective increase in light output over the same range, it is desirable that the series impedance regulating the voltage be in the form of a variable resistance in series with each lamp or, in the case of 2-foot 40-watt lamps, each pair of lamps.

At present there are limitations to the system, which are expected to be overcome in due course. One of these is the fact that the dimming or raising of the lights cannot yet be effected with the same degree of smoothness as with incandescent lamps. In particular, it seems impossible to dim the lamps to zero, the lamps extinguishing themselves while giving appreciable light.

P/L Survey Shows Further Lighting Needed

Over 85% of the lighting in the average American city is inadequate, according to a survey of Indianapolis, Indiana, just completed for the Industrial and Commercial Lighting Equipment Section of NEMA, by an independent market research agency. Indianapolis was selected as a test city for research marketing re'lighting methods in connection with an all-industry program of Planned Lighting.

Analysis of national data had revealed that Indianapolis lighting fixture sales were very close to national average, being better by about 13%. In this average American city, it was found by the survey that less than 20% of the lighting fixtures now in use have been installed since the end of World War II. Approximately three-quarters of these postwar fixture sales have been fluorescent, the balance incandescent.

Footcandle measurements during the survey indicated that at least 85% of the lighting in this average city is inadequate by Illuminating Engineering Society standards. In one group of areas, readings of 46 footcandles and better accounted for only 9% of the total. In these same types of areas over one-third were less than 10 footcandles, and considerably over one-half were less than 20 footcandles.

It is felt that these data indicate the market for lighting is not even approaching saturation. The Indianapolis study shows that the public expects to buy during the next twelve months approximately 24% more lighting fixtures than have been purchased in an average postwar year.

The incidence of lighting fixtures in this typical city is approximately one fixture for every 164 square feet of area to be lighted. Of these fixtures nearly 36% are fluorescent and about 64% are incandescent. Next to getting better illumination, those establishments which installed lighting fixtures during the postwar period, wanted better appearance and improved working conditions—and by their admission they have been extremely well satisfied that these goals have been attained.

With these facts as a base, it is proposed to find out in a comprehensive program not only the best means for promoting Planned Lighting, but also the extent to which it can be sold in the average city, if all elements in the local electrical industry are working together under one direction.

Georgia Section, I.E.S. Celebrates 10th Birthday

Ten years ago a small technical group in Atlanta, Georgia received its Charter as the Georgia Chapter, I.E.S. from the national organization, and so became a pioneer Chapter of the Southeastern Region. Now this Chapter, fully matured into a Section, 135 members strong, and even boasting an addition, Alabama, and a full-fledged Residence Lighting Forum, celebrated its tenth anniversary on the evening of August 22nd. At a time of year when most sections sweltered away into inactivity, 74 enthusiastic members attended the dinner meeting at the American Legion Restaurant.

To dramatize the history of its first decade, seven past chairmen (and three representatives for those absent) lit one of the ten candles on the speakers' table, and each briefly recounted the important activities during his administration. Photographs, meeting notices, and even the original Charter displayed in bulletin-board fashion further highlighted the growth of the organization. Not forgetting the parent body, copies of all the current I.E.S. publications were also exhibited.

EIGHT PAST Chairmen of the Georgia Section assembled in Atlanta on August 22nd to celebrate the Tenth Anniversary of the Section's (then Chapter) Charter Night. Left to right: Walter Nelson, 1944-45; Henry F. Barksdale, 1943-44; James F. Whitehead, 1941-42; Al E. Bruner, 1945-46; Jack H. Murrah, 1949-50; Joe B. Browder, 1946-47; Oren M. Ruff, 1947-48 and Cecil L. Cannon, 1948-49. Absent Chairmen were: Charles Burch, 1939-40; Ivar Stockel, 1940-41 and Hamilton Corey, 1942-43. Each chairman lighted one of the ten candles on the speakers' table as he retold the highlights of his administration.

After a program devoted to the review of past events, the evening was aptly climaxed with the installation of this year's officers, Jack H. Murrah receiving the gavel as Chairman for the coming year. Although J. M. Ketch of the General Electric Co., Cleveland, Ohio, presenter of the original Charter was invited, he could not attend the celebration, but sent a telegram "to congratulate the Georgia Section of I.E.S. on ten years of success and accomplishment. May your next decade be as successful."

"Operation Safety" Promoted by National Safety Council

Bearing the central theme title "Operation Safety," a complete kit of prepared material on traffic safety promotion is being issued monthly by the National Safety Council, 20 North Wacker Drive, Chicago, Ill. The kits contain material designed for local use by newspapers, radio stations, civic organizations and schools.

Geared to the Safety Council's November theme of "Pedestrian Safety," the November kit is a typical example of this service, containing a number of exhibits and information about special posters. A "planning guide for promoting traffic safety" is designed to work as a guiding handbook. Exhibits of some special interest to public support organizations would include:

1. *Traffic Court Conference Announcement*—Of a Traffic Court Judges and Prosecutors' session at Northwestern University Law School, Chicago, October 17 to 21.
2. *Child Safety Posters*—Announcing the "repeat" appearance of two of the most popular panels in the outdoor advertising series. Child safety is stressed as a part of the "Back to School" theme.
3. *The Highway Five*—The National Safety Council presents an outstanding booklet designed to stress the importance of knowing, and obeying, traffic signs to children of elementary school age. The whimsical story of a small boy's dream contains sound advice for adults as well as for young people.

The October kit theme was "Night Traffic Hazards" which included two items submitted be representatives of the Illuminating Engineering Society. One was a four-page item reviewing and condensing the American Standard Practice for Street and Highway Lighting, prepared for the National Safety Council by C. L. Crouch, Technical Director of I.E.S. Another item included excerpts from a sub-committee report "Street Lighting and Traffic Safety," contributed by the I.E.S. Street and Highway Lighting Committee, Stuart R. Williams, Chairman. This outlined the findings of the committee on the relation of street lighting to night traffic safety and included statistics on before and after relighting traffic accidents.

IT SEEMS TO ME

Prefer Standard Nomenclature

To the Editor:

It seems to me I would enjoy and appreciate the technical papers of Moon and Spencer more if they would employ only accepted nomenclature. This is not to criticize their nomenclature *per se;* but until a revised nomenclature has been formally adopted it is difficult to think in its terms. To give in each case the proposed term parenthetically is a distracting interruption, and so does not have the educational value apparently intended.

Perhaps these capable authors could be persuaded to use some other means in their crusade for a better nomenclature.—F. G. Reed, *Hydro-Electric Power Commission of Ontario, Toronto, Canada.*

To the Editor:

In the August issue of Illuminating Engineering, under the heading "It Seems to Me," Domina Eberle Spencer makes the following observation: "I venture to predict that ten years from now . . ." Let me "venture to predict," at least hope, that in less than ten years we will see the vocabulary of Spencer and Moon lowered to the level of us "lower middle-brows" of the lighting industry. We have enough trouble with the necessary lighting terminology without having to struggle with their *helios, logance, pharos, pharosage, blondel,* etc.

We, who are utility, wholesaler, and manufacturer representatives and electrical contractors, represent a ma-

jority (by numbers at least) in the lighting industry. You can identify us as being *Associate* Members of I.E.S. We are limited in our technical education and compared to Spencer and Moon, are low in mentality. Yet it is our responsibility to carry the story of lighting to the classrooms, offices, stores and shops of the country. We believe that we deserve technical information that we can comprehend and use.—C. B. WEEKS, *Kansas Gas and Electric Co., Newton, Kansas.*

Lighting a Press Room

To the Editor:

The August 1948 issue of ILLUMINATING ENGINEERING contains, on page 461, a data sheet on the lighting of a newspaper press room. It is referred to as "an illustration of good lighting practice and to aid in the design of similar installations."

It seems to me that this is not a particularly good example of recommended lighting practice for the following reasons:

Exposed tubing in the general lighting fixtures produces brightness ratios considerably in excess of recommended practice. Using bare lamp fixtures in an attempt to reduce the brightness ratio between ceiling and luminaire is hardly justifiable when industrial fluorescent fixtures are available which allow some illumination to go directly to the ceiling, while at the same time providing shielding in the glare zone.

The statement that "none of the lighting units is in the line of vision during press operations of inspection" is not a very convincing one. What about the time they *are* in the line of vision, which is probably the greater part of the working day?

Incandescent lamps were used for localized lighting based upon "ease of maintenance." Quite the contrary, enclosed fluorescent fixtures are easier to maintain if the cover-glass is coated with a thin application of vaseline. The ink deposit is then easily removed periodically with a putty knife or some similar tool and a new coating of vaseline applied.

The figure of 30 footcandles indicated for maintained general illumination seems high since the calculated value is closer to 20. This is based on the output of eight fixtures with three 40-watt lamps in each.—FLOYD SELL, *Detroit Edison Co., Detroit, Mich.*

Editor's Note: Comments from readers of ILLUMINATING ENGINEERING regarding Lighting Data Sheets, articles, or other material published are welcomed at all times. The Technical Data Sheet Committee agrees in general with Mr. Sell's criticism of the Data Sheet on "Lighting a Printing Plant," as published. The Committee advises that its approval of this Data Sheet was based primarily on the application of the incandescent floodlights with glass covers, and the inherent ease of maintenance. In preparing the copy for publication, however, major emphasis inadvertently was placed on the general lighting of the press. Since this general lighting is provided with bare lamp fluorescent luminaires, the impression is given that bare lamp lighting is sanctioned, which was not intended.

The Committee's inquiry as to the use of bare lamps brought the statement that the existing conditions (dimensions of the shop and placement of the presses) were such that the bare lamps are not within the normal field of view. There remain, of course, the questions as to whether published recognition should be given to any bare-lamp installation however qualified, because of the inference of approval that may be gathered by the careless or uninitiated reader.

ABOUT PEOPLE

G. B. Buck, II, for a number of years a well-known member of the engineering division staff of the General Electric Co., Nela Park, Cleveland, Ohio, has been transferred by that company to their Rocky Mountain District in Denver, Colorado. Mr. Buck will serve as District Engineer.

Charles W. Carr has been appointed Wakefield's sales representative for the Pittsburgh territory, according to an announcement by F. I. Wilson, sales manager of the F. W. Wakefield Brass Co., Vermilion, Ohio. During the war years, Mr. Carr served as the Washington representative for the National Supply Co. of Pittsburgh.

Leonard May, representative in the province of Ontario for the Wiring Device Division of the Renfrew Electric Co. Ltd., and the Temco Electric Mfg. Company of Montreal, announced the appointment of **Jack A. Murray** to his staff. Mr. Murray is a graduate of Canadian Electronics Institute, and comes to his new connection from the Canadian General Electric Co. Ltd., where he spent some time in various departments.

Leonard Wells has been appointed executive assistant to W. J. Wylie, manager of power sales of the Toronto Hydro Electric System. He succeeds the late **W. D. Corcoran.** Mr. Wells was previously power representative in the Toronto Hydro downtown district.

Thorndike Saville, dean of engineering at the New York University, has been elected president of the American Society for Engineering Education for the year 1949-1950.

James H. Campbell, formerly division manager of Consumers Power Company's Grand Rapids division, has been appointed assistant to the president and transferred to the general offices in Jackson, Michigan. Mr. Campbell joined Consumers in Lansing in 1933 as power and lighting sales engineer. From 1940-1942 he was with the Ohio Edison Company in Youngstown. After spending four years in military service, he joined the Grand Rapids Division of Consumers Power three years ago, first as assistant division manager, later being appointed division manager.

E. W. Gutelius has been named to direct advertising and sales promotion for the lamp and fixture divisions of Sylvania Electric Products Inc., New York, N. Y. He was formerly assistant sales and promotion manager for the lamp department of the General Electric Co.

The Jefferson Electric Co., Bellwood, Illinois, has announced the election of **J. M. Bennan** as president. Mr. Bennan succeeds James C. Daley who has been made chairman of the board.

James E. Woodall has been named manager of the Fairmont, West Virginia plant of the Westinghouse

Lamp Division. Mr. Woodall, a graduate of New York University, joined Westinghouse 25 years ago at its Belleville, New Jersey plant and was manager of this plant at the time of his recent appointment.

E. Donald Gray-Donald, chief engineer of the Quebec Power Company and Quebec Railway, Light and Power Co. has been announced the new president of the Canadian Electrical Association.

J. Eliot McCormack will head the new transmission and distribution bureau as chief distribution engineer of Consolidated Edison Co. of New York, Inc. Mr. McCormack began his career in the utility industry with the New York and Queens Electric Light & Power Co. and was serving as distribution engineer for Queens when he was transferred to Consolidated in 1938.

OBITUARY

The loss of one of the Society's earliest members has been reported in the recent death of **Robert B. Ely** of the Civil Aeronautics Administration, Chicago, Illinois. Mr. Ely joined the Illuminating Engineering Society early in 1907, the second year of its existence, and served for many years as officer, member of Council and on numerous committees. A valuable contributor to the early *Transactions*, Mr. Ely's first paper was published in 1908. He was the author also, of numerous articles on illumination in the trade press, and a noted lecturer on the subject, especially at educational courses on lighting.

Before his association with the CAA, Mr. Ely was connected with the Westinghouse Electric Corp., Boston office, where he was in charge of educational courses for salesmen.

Mr. Ely was a director of the Society from 1921 to 1924 and was an active committee member of I.E.S. from the Society's earliest activities (1908 to recent years (1941) when he was elected Chairman of the New England Section for a second term.

LIGHTING CALENDAR

Society Events

October 13, 1949 — Meeting of I.E.S. Council, Society Headquarters, New York City.

Industry Events

October 4-6, 1949—Fifth Annual Meeting, Canadian Electrical Manufacturers Association, General Brock Hotel, Niagara Falls, Ont.

October 11-14, 1949—American Standards Association, Annual Meeting, Waldorf-Astoria Hotel, New York, N. Y.

October 12-15, 1949—International Association of Electrical Leagues Fourteenth Annual Conference, Cleveland, Ohio.

October 12-15, 1949 — Electrochemical Society, 96th convention, La Salle Hotel, Chicago, Illinois.

October 13, 1949—Fifteenth Anniversary Celebration of Better Light Better Sight Bureau and Testimonial Dinner for Glenn Trumbull, Commodore Hotel, New York City.

October 24-28, 1949 — 37th National Safety Congress, Chicago, Ill.

November 6-8, 1949—Southeastern Industrial Vision Congress, Georgia Institute of Technology, Atlanta, Ga.

November 8-14, 1949—National Electrical Contractors Association 1949 Annual Convention, Rice Hotel, Houston, Texas.

November 14-18, 1949—National Electrical Manufacturers Association, Chalfonte-Haddon Hall, Atlantic City, N. J.

December 4-7, 1949—The American Society of Refrigerating Engineers, 45th Annual Meeting, Edgewater Beach Hotel, Chicago, Ill.

December 26-31, 1949—Meetings of the American Association for the Advancement of Science, Hotel Statler, New York, N. Y.

January 16-19, 1950 — Winter Conference of the Canadian Electrical Association, Chateau Frontenac, Quebec City.

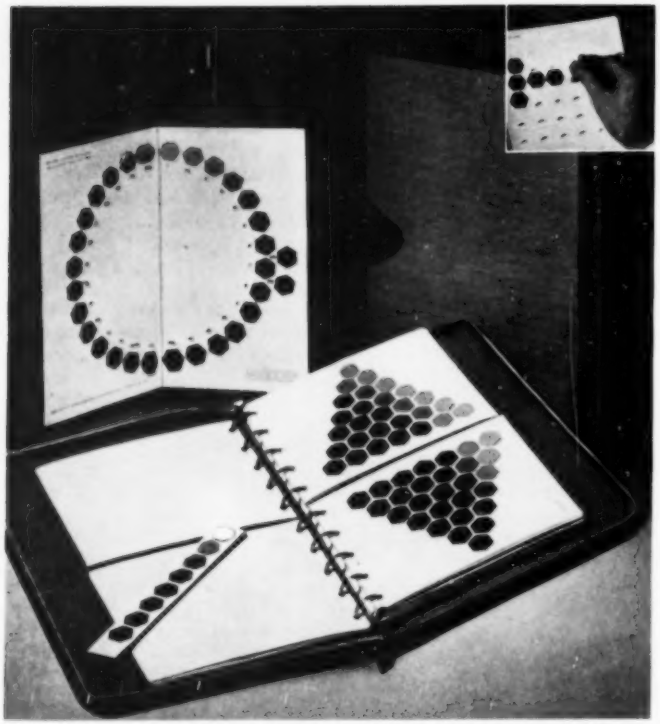
BOOKS AND PAMPHLETS

Color Harmony Manual — Third Edition by Egbert Jacobson, Walter C. Granville and Carl E. Fross, published by Container Corporation of America, 38 South Dearborn Street, Chicago 3, Illinois. Price $1.13.38. Although published under a 1948 date line, this edition did not become available for distribution until this summer. Measuring 11 x 16½ inches, this leather-bound zippered ring-book represents a new presentation of the Ostwald Color System, brought down to date in the light of experience achieved through the distribution and field use of the thousand copies or so of the first two editions.

The manual contains 37 separate charts and 943 different color chips, instead of the 680 color chips contained in previous editions. It has 30 hues instead of 24 in the hue circle, and a duplicate hue circle also, 9 grey steps instead of 8, and 12 extra near-grey shadow series, each with 7 steps. Two work charts are provided for experiment and study.

Recent developments in colorants have made possible the extension of the color range in many regions without sacrifice of permanence and other stability factors. In particular, the light clear series in the red-to-purple region has been made much clearer; small gains of a similar nature have been made in most other hues. The extra colors included in this edition were selected on the basis of their general industrial usefulness, and are notated in accordance with the Ostwald "unabridged method of notation." The 6 extra hue charts provide a better coverage in the yellow, blue and red regions. The extra units in the shadow series extend the coverage in the important near-grey region. Extra equal-black series have been provided in the yellow region.

The regular 8-step Ostwald grey scale is provided on a separate strip, to facilitate its placement on any hue chart to complete the monochromatic triangle, or to complete the transition between triangles of different hues. Duplicate chips for the 34 colors are included with the new circle chart, for convenient reference. These color chips were made by applying a mat pigmented lacquer of appropriate



Color chips of Color Harmony Manual are easily removable for practical use.

color to one side of a sheet of clear transparent cellulose acetate. This provides a washable color having a mat surface on the side of the coating, and a glossy surface on the reverse. Pigments of maximum permanence were used in a vehicle composed of cellulose acetate. The chips are hexagonal in shape and about an inch across and made with a tab extension on one edge to facilitate their use in building compact color triangles for comparison purposes. A 54-page booklet of detailed and comprehensive instruction completes this manual.

One of the most important features of this new edition, as emphasized by its publisher, is the ability of the user to order paints custom-mixed to match the dull side of any of the color chips in the manual. This is expected to "make the execution of a paint color scheme, simpler, more accurate, and more economical ... this feature will become operative in three or four months."

Until recently, nearly all of the technical discussions relating to daylighting of enclosed spaces through windows have been confined to the journals of the technical societies or to manufacturers' literature. Two new books on the subject have appeared recently. One is by British and the other by American authors. These books are easy and profitable reading, and American architects, structural and lighting engineers should be delighted with both. Each book treats a different phase of natural lighting and uses a different style and approach.

The British book is entitled *Building for Daylighting* by Richard Sheppard and Hilton Wright, with an introductory historical note on English window design by John Gloag (printed in Great Britain, distributed by the Macmillan Co., New York, at $5.50).

The American book, *Windows in Modern Architecture* is written by Geoffrey and Bruno Funaro (Architectural Book Publishing Co., Inc., 112 West 46th St., New York 19, N. Y.; Price $8.50).

John Gloag's historical notes on the development of the art of glass making and the concomittant development of ancient and medieval British architecture make fascinating reading. With interesting sketches to illustrate the text, he covers twenty centuries of slow, but sure progress, amid the discouragements of feudal battles, international wars and domestic oppressions; and he tells of the ingenuity and skill of artisans and craftsmen in overcoming difficulties. To give historical authenticity and to encourage further research, the author concludes his part of the book with a twenty-one item bibliography.

In the next section, by precept and example, the authors explain what has been accomplished in the way of good daylighting practice. These examples are well chosen and range from individual rooms, schoolrooms, separate buildings, blocks of buildings, etc. to town planning—orientation and location. Results only are shown, but for the most part they are in accord with good American practice. This section will prove useful both as reference material and as a source of information for technicians designing their first building with good daylighting as one of the principal requirements. It would have been of even greater value if the authors had covered more fully several pertinent topics. There is no discussion of the "how and why" of daylighting mathematics. Although mention is made of such tools as "Daylight Protractors," "Waldram Diagrams," "Burnett Diagrams," and "The Heliodrom," the description and use of these tools has been omitted. Also, a more detailed discussion of the problems of glare and reflections would have been a definite contribution to this aspect of daylighting.

The final section is devoted to thirteen "axonometric" ("isometric" in our terminology) cut away drawings showing as many different types of buildings. On facing pages opposite each drawing is a specification recommending the kind of glass to be used in the various locations. Three of the drawings are concerned with housing, single and multiple apartments which promote a scale of living seldom if ever encountered in pre-war British architectural magazines. The examples shown of schools, welfare centers, hospitals, hotels and department stores compare well with those found in the best American architectural magazines.

Windows in Modern Architecture is presented more or less as a technical note book, such as an architectural student or draftsman might assemble for his own reference over a period of years. These notes are organized into seven sections or chapters.

Section 1, "Why is a window," focuses the reader's attention on the four fundamental functions of a window: (a) to let in daylight for light's sake and to let in the sun for the sake of its health giving properties; (b) to assist ventilation; (c) to permit vision outward and (d) to provide a decorative feature for the building facade. The marginal thumb nail sketches and comments are an excellent way to illustrate and clarify the text. For this reason the chapter is easy reading, complete and by far the best in the book.

Sections 2, 3, and 4 are devoted to Opening Sash, Basic Types; Stock windows; and Installation details. The most valuable part of these sections is the development of criteria for judging window quality when making selections from the multitude of so called stock types.

The authors have done a much needed job of classifying the many different kinds of windows available, thus bringing order out of the confusion of the mass of data usually found in architectural and window manufacturer's catalogs. The advantages of each basic type (i.e. Double Hung, Casements, Projected etc. types) along with its limitations have been presented. Typical details of construction of each type are presented and the merits and limitations emphasized and checked against the criteria of selection. Likewise metal windows have been compared to wood windows.

Section 5 reviews 63 window installations and is called "Windows in Use." Part of the industrial jobs are good examples of good daylighting practice. At least two of the illustrations show poor practice, a waste of glass and total disregard of the elementary principles expounded by recent Illuminating Engineering Society "Recommended Practices."

Section 6 comprises one of the best discussions of *glass* for daylighting equipment that has appeared recently. This chapter might be better for additional discussions of light directing or prismatic sheet glasses and on the possible need and application techniques for them. Likewise the discussions on glare reducing and heat absorbing and reflecting sheet glasses might have been amplified. In spite of its shortcomings this chapter makes good reference material.

The final Section 7 embodies subject matter for several classroom lectures and in one of them Mr. Funaro develops the Funaro "Sunfinder," an instrument for determining the sun's penetration into a room at any hour or any day in the year, and from this, working backward to find out the cut-off required so that a balcony-like sun shade will be effective in excluding the summer sun and utilizing the winter sun for solar heat. Another classroom lecture subject deals with solar heat gains and losses, including quantitative evaluations thereof and especially through glass. The final subject for discussion has to do with condensation on windows.

These subjects are, without question, a necessary part of the field of the Natural Lighting Engineer and have a rightful place in any text book. As here presented the text is somewhat abbreviated for casual reading. Plenty of source material is available and in future editions it is to be hoped that Mr. Funaro will elaborate this chapter.

The authors also overlooked an opportunity to develop a textbook by failing to go into the mathematics of daylighting. Plenty of source material is available. It may be buried in the musty covers of scientific society papers, but would need only to be resurrected, clarified and made appetizing. In a pioneering effort such as this, one can hardly expect perfection and complete coverage.

The 1949 *Heating, Ventilating and Air Conditioning Guide* is now available at $7.50 per copy from the American Society of Heating and Ventilating Engineers, 51 Madison Avenue, New York 10, New York. Eighty pages of new material have been added and half the chapters revised since the 1948 edition. Subjects treated include Principles, Human Reaction to Atmospheric Environment, Heating and Cooling Loads, Combustion and Consumption of Fuels, Heating Systems and Equipment, Air Conditioning, Special Applications, Installation and Testing Codes.

Sportsmanlike Driving; published by the American Automobile Association, Washington, D. C.; second edition, edition, 1948. Written primarily as a text for beginning drivers, this book will also help present drivers and pedestrians to improve their roadway habits. Under the present system of driver "education" many bad habits are handed down or allowed to develop. One of the twenty-four chapters deals with "The Eyes of a Driver" including several pages on "seeing at night." Other sections of possible interest from a lighting standpoint relate to the care and operation of headlights.

Westinghouse sound motion pictures and slide films for education and entertainment programs are described in a new 46-page booklet announced by the Westinghouse Electric Corp. The booklet discussed the no-charge basis on which the films can be borrowed, and information on the available size, projection time, type of film, and shipping weight is given for each film listed. Complete instructions for ordering the films are included as well as information on the operation, care, and handling of the films. For a copy of the booklet (B-4273), write Westinghouse Electric Corp., Box 868, Pittsburgh 30, Pa.

Sources of Engineering Information, by Blanche H. Dalton. Published 1948 by the University of California Press, Berkeley and Los Angeles, Calif.; also by Cambridge University, London, England. Price $4.00.

This compilation is the revised edition of a syllabus originally written to be used with lectures on the use of the library, presented for engineering faculty members and graduate students interested in learning how to make effective use of library facilities when engaged in research. The arrangement is based upon actual library usage, and is designed to enable the technical man to find the key to research previously published in a particular field by turning to the alphabetical topic listing representing that field. The volume seems to contain some information on practically every type of engineering. In addition, important source material is briefly described and its use explained.

Establishment and Maintenance of the Electrical Units—A description of

the new system of electrical measurement using "absolute" units, adopted by the International Conference of Weights and Measures and officially instituted January 1, 1948, is described in a new booklet of the above title, just published by the National Bureau of Standards and available from the U. S. Government Printing Office.

The purpose of this booklet is to record an account of the working of the international system of electrical units, with particular reference to the maintenance of the international units in the 37 years preceding the adoption of the new units; to point out the trends of development that made them obsolete; and to record the official steps by which they were superseded. Also described are the methods used in the measurements that now form the basis for the new absolute units, in which all certifications for standards and instruments are now given by the National Bureau of Standards. In addition, United States laws, important conferences and resolutions pertaining to the adoption of the new units are reproduced in the appendices of the booklet.

Circular C475 *Establishment and Maintenance of the Electrical Units*, by F. B. Silsbee, 38 large double-column pages, illustrated with 23 diagrams, halftones, and tables, 25 cents a copy, available from the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C. Remittances from foreign countries must be made in United States exchange and must include an additional sum of one-third the publication price to cover mailing costs.

An interesting excerpt from an article titled "Fatigue in Industry," June, 1949 issue *Industrial Health Bulletin*, Canada reads as follows:

Lighting is another important environmental factor affecting fatigue. Today there are many occupations demanding close visual attention which require adequate illumination and freedom from glare. In plants having inadequate lighting standards, poor work records, increased accident rates and lowered working morale may result. The installation of modern lighting equipment to bring the light level at working surfaces up to recommended standards for the particular job is part of any program directed towards the reduction of industrial fatigue.

I.E.S. Medal Nominations Due by January 1st

Members of the Society are invited to submit nominations to the Medal Committee up to January 1st, according to the procedure under which the Committee now operates. The Rules of Procedure adopted by the Committee in 1945-1946 include the following instructions:

Candidates for the award need not be members of the Society, and may be nominated at any time by any voting member of the Society, by presenting to the Committee on Award the name of the individual whose accomplishments in his field are deemed worthy of such recognition. Each nomination should be accompanied by a comprehensive statement of the candidate's achievements, whether it be in the field of engineering, design, applied illumination, optics, ophthalmology, lighting research, education, or administration and management.

In order for a candidate to be considered for the award of a given year, the following shall be delivered at the General Office before January 1st—(a) A written nomination giving personal and general information to fully identify the candidate. (b) A statement of the candidate's achievements, on which the recommendation is based. This statement shall be signed by the person responsible for the information, not necessarily a member of the Society, if known otherwise, also giving the names of four persons, preferably I.E.S. members, who can testify to the candidate's achievements.

Previous awards of the I.E.S. Medal, established in 1944, have been made to George H. Stickney, Preston S. Millar, E. C. Crittenden, Matthew Luckiesh, Sir Clifford Paterson and Ward Harrison. The Medal was established for the purpose of giving recognition to meritorious achievement which has conspicuously furthered the profession, art or knowledge of illuminating engineering.

Nominations should be sent to the I.E.S. Medal Committee in care of the General Office of the Society. Inquiries concerning nominations may be addressed to the Executive Secretary, A. D. Hinckley, at headquarters.

Current Articles on Lighting

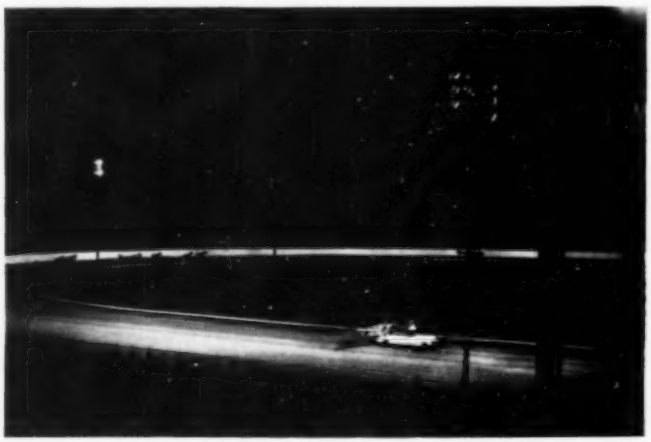
The following list presents titles and source of publication of current articles on lighting and allied subjects which have appeared in recent issues of nationally known magazines having a wide circulation.

Anodized Aluminum Reflectors, by V. F. Henley, *Electrical Review*, July 29, 1949, p. 213

Seattle's Transportable Schools, by Francis E. Huggard, *School Board Journal*, August, 1949, p. 33

Swirling Patterns, *Signs of the Times*, August, 1949, p. 66

Continued on page 19A



HARNESS RACERS warm up prior to the start of a race at the brilliantly lighted, new Ocean Downs Race Track at Ocean City, Maryland. Track is illuminated with the same type of floodlights used for night ball games at Briggs Stadium, Detroit, and Yankee Stadium, New York.

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Chapters this year. Photographs of the 7 other Chairmen were not available.

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Not available at time of press.

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Lamps: 40 watt, 3500° white
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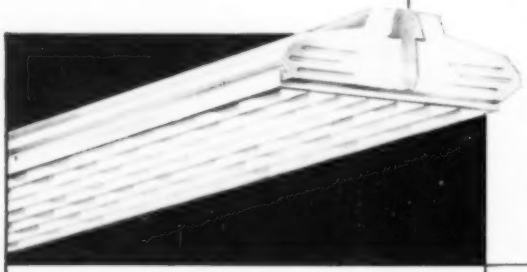
Whether your clients are interested in selling more goods or in increasing visual efficiency, you'll find it will pay to prescribe Litecontrol fixtures. In this wide line, there are sturdy, graceful units that smoothly blend with any architectural design. All are extra-sturdy in construction, easy to install, built to give your clients more years of ample, glareless light with minimum maintenance. Write today — we'll be glad to help you by supplying complete lighting layouts.



. . . with LITECONTROL NO. 4044 FIXTURE

Offering full light distribution with low surface brightness, this fine Litecontrol unit is also distinguished by unusually low installation and maintenance costs. Hinged louvers swing down for easy lamp replacement and cleaning.

Cat. No.	No. of Lamps	Length	Width	Height	Approx. Ship. Weight
4044	4-40W	49"	16"	5¼"	44 lbs.
4000-20 Downlight reflectors					6 lbs.

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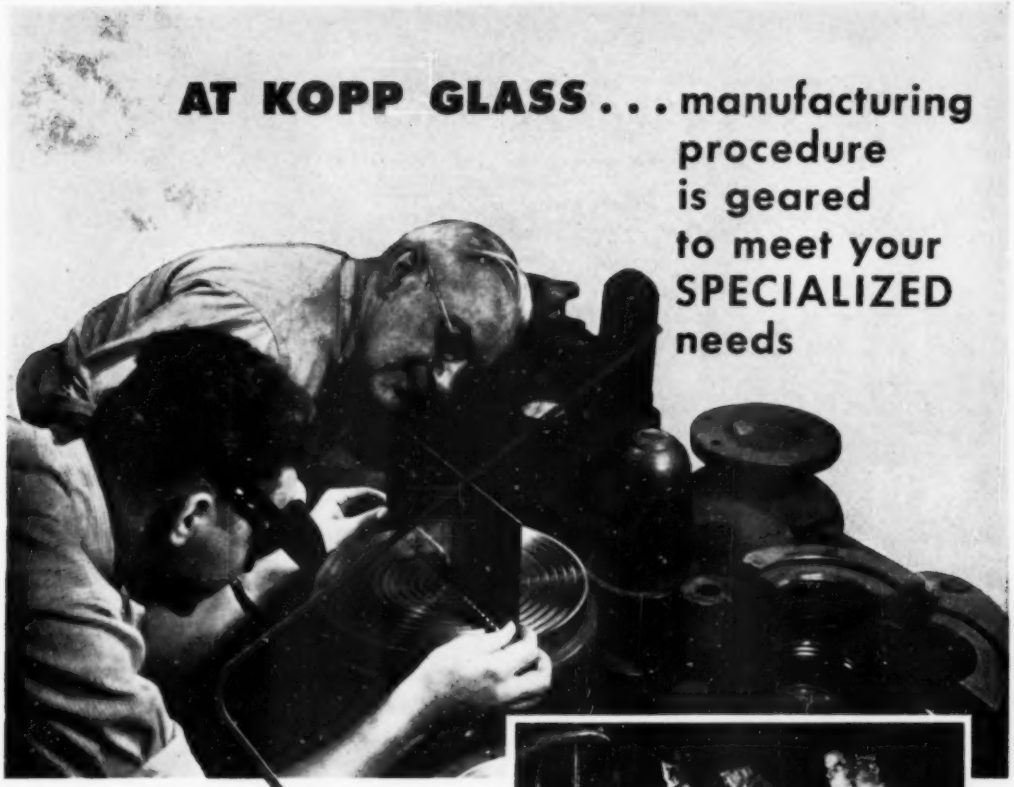

To provide the beam control, color transmission, resistance to service conditions, dimensional accuracy and other characteristics your lenses and roundels must have, KOPP GLASS offers a completely integrated engineering and manufacturing organization. Everything we make is *special*—made to meet a customer's specific needs.

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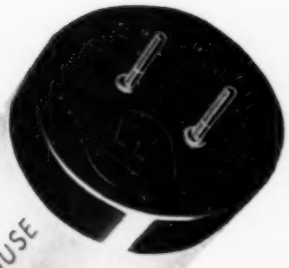
To assure top quality glass—specify KOPP!

(Top) Checking a lens mould with precisely-cut template, before releasing for production. (Above) Preliminary inspection of a newly pressed lens. (Below) Color and light transmission of regular production are checked with modern laboratory-type equipment.

KOPP GLASS, INC. KOPP GLASS SWISSVALE, PA.

Westinghouse

Fluorescent Lamps



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...YET COST NO MORE!

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SAVE THIS– ONE LAMP NOW LASTS AS LONG AS 3.

LAMP COSTS

TIME SPENT REPLACING BURNED-OUT LAMPS

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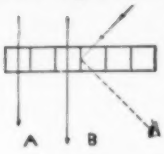
TO WORK ON YOUR NEXT LIGHTING JOB!

Available now in any quantity—attractively priced

Corning FOTA-LITE glass louvered panels can be used in many types of recessed or pendant lighting fixtures, as well as, for continuous row or completely illuminated ceilings. It is available now in any quantity at attractive prices.

✔ CHECK THESE IMPORTANT ADVANTAGES:

1. Fota-lite assures a 45° light cut off.
2. Fota-lite can be cut to fit almost any standard fixture where louvers or glass panels are desired.
3. Fota-lite has no sag or cold flow—it is glass. No special construction is needed for its support.
4. Fota-lite louvers do not loose efficiency over an extended period of time—they are part of the glass.
5. Fota-lite permits dust-tight fixture construction and thereby easy maintenance because only a single flat surface need be cleaned.
6. Fota-lite causes little contrast in brightness between the light sources on opal vertical surfaces because of large number of louver cells. White louvers are non-color selective.



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B. Diffusing louvers intercept and eliminate eye-level glare.

FOTA-LITE makes possible shallower, dust-tight installations.

The smooth glass surface of FOTA-LITE is easy to clean.

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Send me Fota-lite demonstration card showing how Fota-lite diffuses and cuts off light at 45°.

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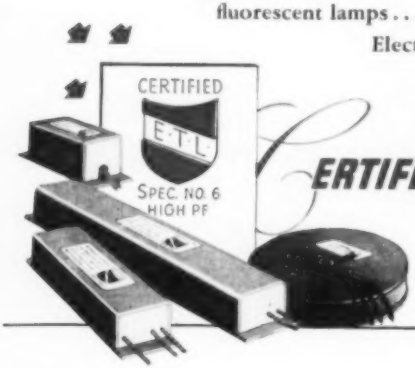

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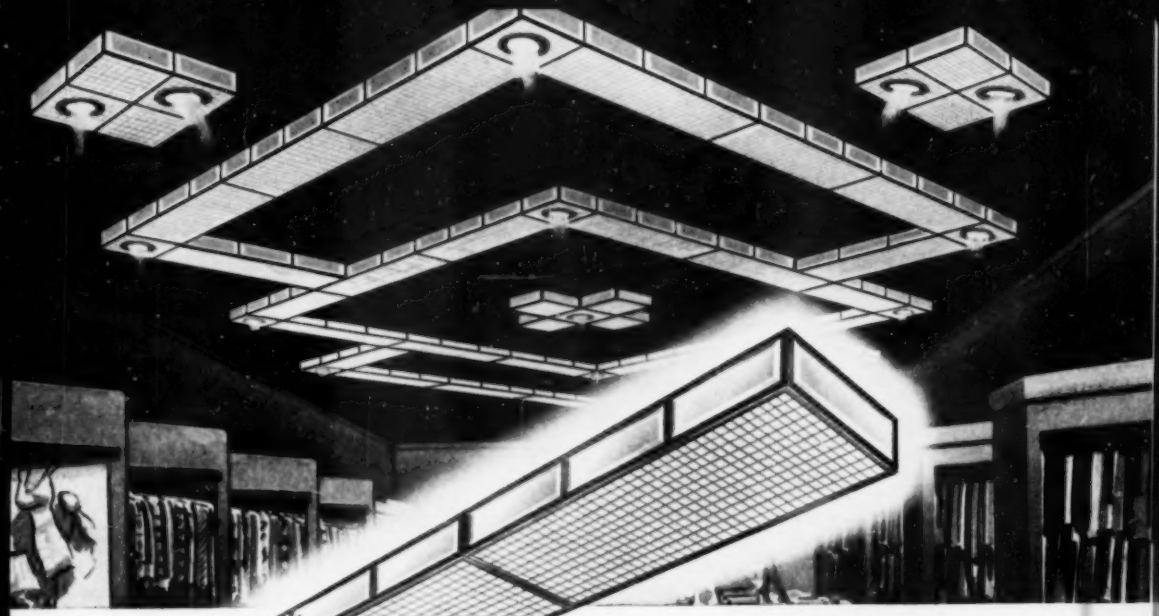

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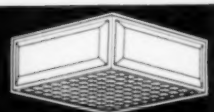

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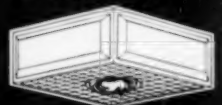

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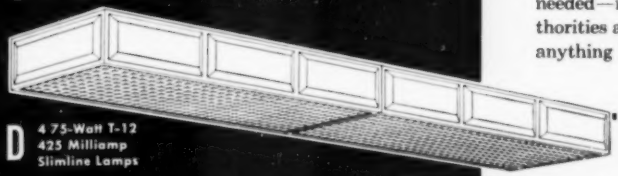

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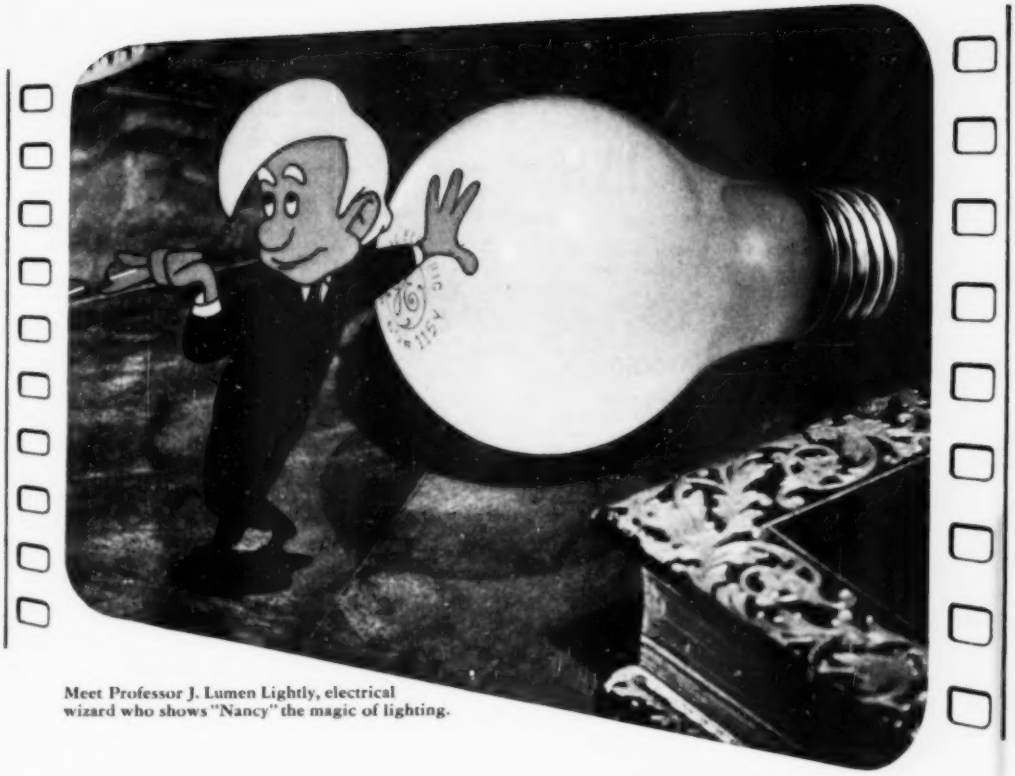

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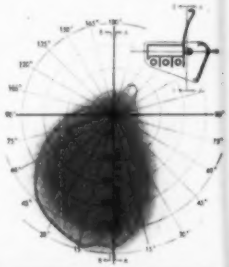

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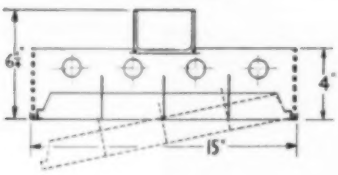

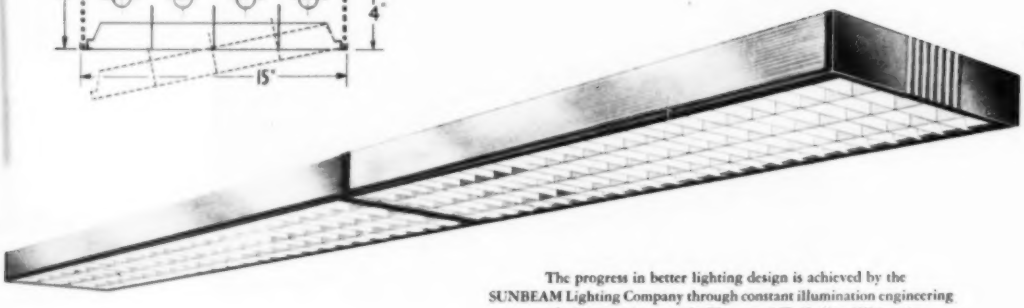

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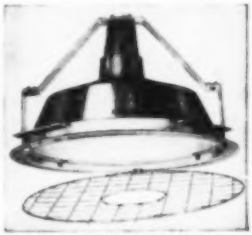

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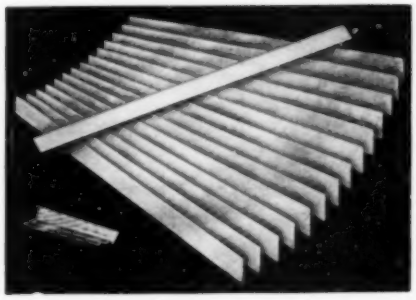

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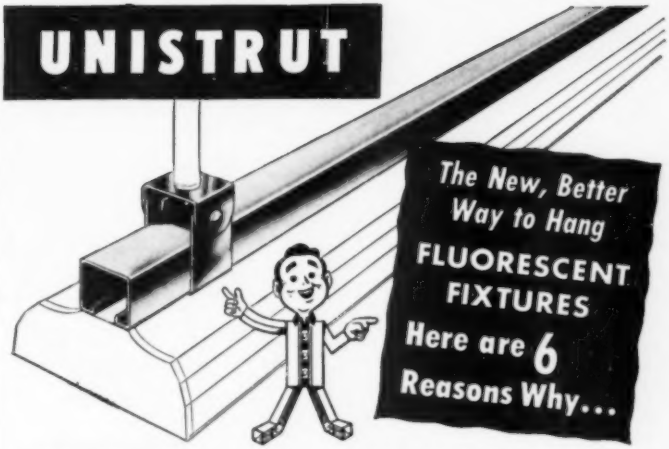

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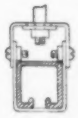

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Informed electrical and lighting men know the importance of high quality starters and lampholders, in terms of easy maintenance, reliable starting and reliable operation.

They know that poor electrical and mechanical design can cause high temperature operations of the ballast resulting in decreased ballast life.

They know, also, that lamp life is shortened by a ballast which supplies low starting current or by one that delivers low operating watts to the lamp. They know that low power factor ballasts do not permit efficient utilization of present wiring. They know that well designed and well constructed lighting units, such as those made to RLM Standards, will stand up and give full satisfaction to the customer.

The Remedy

It is up to the entire Lighting Industry to put this knowledge to work for the benefit of the public. This can best be done by first furnishing customers with the facts about initial cost, maintenance cost and performance of fluorescent lighting equipment and by supplying equipment which is warranted by the manufacturer and certified by an independent testing agency as meeting recognized and published standards of design, construction and performance.

This Advertisement is published in the Interest of the Entire Fluorescent Lighting Industry by

RLM STANDARDS INSTITUTE
INCORPORATED
The letters RLM stand for Reflector and Lighting Equipment Manufacturers
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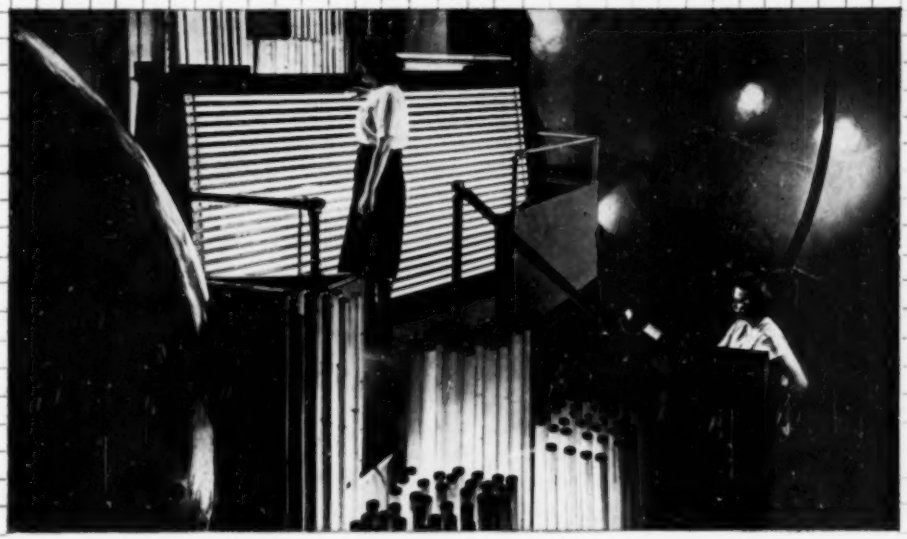
CHICAGO 6, ILLINOIS

F-2263

QUALITY CONTROL DATA SHEET

SYLVANIA FLUORESCENT LAMPS



EVERY 60 MINUTES, QUALITY OF SYLVANIA FLUORESCENT LAMPS IS CHECKED WITH BIG PHOTOMETER

To insure lamps that are unsurpassed, Sylvania quality control engineers take *hourly checks* of production line lamp samples in this huge 15-foot diameter Photometer! This high-speed unit allows fast, accurate checks on light output and electrical characteristics. It serves to *keep* Sylvania Lamps "The Best Light In Sight!"

In addition, samples of *each day's output* are tested against lamps of other brands—further insuring that the Sylvania Lamps shipped everywhere are unbeatable! This supervision of lamp quality consists, too, of testing light output at various stages of lamp life . . . of determining voltage and current characteristics.

This huge unit is just one of many *extra-quality controls* employed at Sylvania to make sure *Sylvania Lamps are the best buy in fluorescent illumination!* That's why they give *far more light*, have *longer life* than ever before!

For full information on the entire Sylvania line, write Advertising Dept. L-8510, 500 Fifth Ave., New York 18, N. Y.

SYLVANIA ELECTRIC

FLUORESCENT LAMPS. FIXTURES. WIRING DEVICES. SIGN TUBING. LIGHT BULBS. PHOTOLAMPS. RADIO TUBES. CATHODE RAY TUBES. ELECTRONIC DEVICES